The Camelid
An all-purpose animal

Volume I

Proceedings of the Khartoum Workshop on Camels December 1979

Editor
W. Ross Cockrill

Scandinavian Institute of African Studies, Uppsala
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FOREWORD

In 1979 the International Foundation for Science (IFS) took the initiative in arranging a workshop on camelids. This was held in Khartoum, Sudan, in cooperation with the Agricultural Research Council of the Sudan National Council for Research. Dr. B. Göhl (IFS) was responsible for ensuring the cooperation of the many experts on the camelids. The outcome of these efforts was a conference which became a landmark in the hitherto largely disregarded research on the camelids.

The preliminary papers of the meeting was published in a limited edition as an IFS report. The demand for copies has been heavy, especially from people actively involved in dry-land problems. The contributors were invited to revise, update and expand their manuscripts which were then edited by Ross Cockrill. The Scandinavian Institute of African Studies is privileged to publish the proceedings. The present volume comprises an introduction by the editor, the original amended contributions and some additional requested papers. A second volume will appear in the form of a bibliography.

I have personally noted the great interest in the outcome of the Khartoum conference, particularly among research workers in the Third World. It is my hope that this publication will fill a gap in the available literature and will stimulate the growing interest in camelids in the context of rural development.

Uppsala, November 1984

Anders Hjort
Director
Scandinavian Institute of African Studies
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INTRODUCTION

The Camelidae are among the most neglected and ignored of mammal families. They are the small group which consists of the dromedary and bactrian camels, and the alpaca, guanaco, llama, and vicuña of South America. No other domestic animals are so well-adapted to their environments as the camelids and none are so well-equipped to meet the demands that are made on them: they survive, produce and work in the harsh environments of bush and altiplano and the vast deserts of Africa and Asia.

The camel must not be regarded as indicative of a primitive or backward civilization. In terms of production it is probably the most efficient domestic animal, and all outputs are capable of being increased by improved husbandry and controlled breeding. The potential is there, awaiting the techniques of scientific exploitation. It must be appreciated that when better quality fodder and feed, salt and pure water in quantity are freely available, camels will not merely subsist, but will grow rapidly, increase in weight and size, breed regularly, yield much more milk and exhibit the characteristics of the classic meat animal.

The International Foundation for Science (IFS), located in Stockholm, Sweden, supports scientists in developing countries, not only by giving research grants, but also by arranging seminars, workshops or conferences on scientific subjects. At such meetings participants provide written texts to their reports or lectures. In December 1979, IFS in cooperation with the National Council for Research of Sudan, held a Workshop on camels in Khartoum. The participants were scientists, administrators and anthropologists from many of the countries in which camelids are animals of economic importance. A report of the meeting was subsequently produced as IFS Provisional Report No. 6. The current presen-
tation consists of the numerous communications which were presented at the Workshop, with some additional invited contributions. In many cases the original papers have been substantially amended by the authors, and the edited report is now presented. In no sense can this be regarded as the definitive volume on the Camelidae. That has still to be written, and there is a real and growing need for it. The present publication is submitted as a contribution to the knowledge of a vitally important group of animals which are in some danger of lapsing into anonymity, obscurity and the neglect which may presage extinction. A distinguished assembly of working scientists here presents the case for the camelids and indicates the research required and the steps which must be taken to improve the quality, productivity and reproductivity of these animals.

One of the reasons for the neglect and the complaisant acceptance of what the animal has to offer is that camelids for the most part exist in countries which used to be referred to as underdeveloped where, until relatively recent times when they became "developing", there were few if any facilities for research, and little guidance or incentive for owners and breeders to improve the quality and capacity of their stock. The self-sufficient camelid is there, it is a fixture, immutable and unchanging, and accepted as part of the cruel ambience in which man and his animals seek survival.

Domestic animals in all countries under all climatic conditions and at varying altitudes are an integral part of whatever agriculture may exist but, in greater measure than any other animal, the camelids are also part of the history, traditions, economy and culture of the countries which are their homelands.

It has been said, by someone who did not regard the committee approach with favour and it has been repeated, often by those who ought to know better, that the camel is an example of an animal put together
by a committee. If the statement were true it would be a complete vindication of the committee in action, for here is a group of animals so superbly adapted to their harsh and exacting locations that they thrive where other species decline and die. They offer the only means of utilizing great areas of the earth's surface, and of obtaining an offtake in the form of work and edible protein. Their feed and water needs are minimal. They browse and graze on vegetation which is inaccessible to or ignored by other animals, and they have a remarkable tolerance to dehydration.

Despite such inhibitions created by "underdevelopment" as isolation, lack of communications, antipathy to investigation, security considerations, shortage of scientists and technicians and many other impediments, valuable work has been done over the years and much of the published literature on camelids, though relatively sparse, is significant and impressive. In recent times two of the scientists who participated in the IFS Workshop and contributed materially to its deliberations, Dr M.F.A. Farid and Dr D. Richard, have published impressive bibliographies which are valuable guides to the literature and to the history of camel studies. Much work, however, has gone unnoticed: some of it is in the form of forgotten reports gathering dust on the shelves of government departments, some exists only as verbal reminiscence.

Use of the camel in its classic role as a transport animal, the aptly named "ship of the desert", has declined in the last few decades, although the world population of camels, according to the Food and Agriculture Organization of the United Nations (FAO) has shown a steady increase. The present world total of camels is estimated at approximately 17 million and of the other camelids at 7.5 million.

Outside of South America, little is known or appreciated of alpaca, guanaco, llama and vicuña, the camelids
of the Altiplano, the high plateaux of Argentina, Bolivia, Chile and Peru. The guanaco and the vicuña exist mainly in the wild state in forests and mountain areas: their skins and wool are greatly prized. The llama is a competent pack animal. Tha alpaca is a robust, wool-producing animal. All the South American camelids are valuable sources, potential or actual, of meat, milk, wool and hides. Much research is required to ensure their proper development and fuller exploitation.

The one-humped camel or dromedary of the hot deserts of Africa and the Middle East is the camelid which exists in greatest numbers and which, in the past, has attracted the most attention. The two-humped or bactrian camel inhabits the cold deserts and arid grasslands of central Asia, mainly in China and Mongolia, and is a valuable pack and riding animal producing quality wool and having a notable potential for milk and meat production.

As long as there are deserts and nomads there will be a need for the pack and riding camel. The great camel caravans have not yet entirely disappeared. Though the days of the pilgrim caravans of over 10 000 camels travelling from Cairo and Damascus to Mecca are long since over, the Saharan salt caravans still make the three-week journey from Taoudeni to Timbuktu.

As the need for the camel as work animal or a beast of burden declines, the emphasis is shifting to the production of meat and milk which is an iteration of what began to happen over a hundred years ago with cattle in Europe. The maintenance of camels for such purposes is not incompatible with nomadism: camel milk is the basic diet of most desert nomads and meat is eaten on special and ritual occasions. The settled intensive rearing of camels on irrigated land for meat and milk, however, is possible on a large scale and under good management it has been shown that females can calve every 18 months. The meat of young camels, reared and fed for slaughter at or below 4 years of age, competently killed, dressed
and butchered is tender, palatable and acceptable to the consumer. Camel milk generally has a fat content of under 4 percent and is rich in vitamin C, which is highly important to the desert consumer. Yields vary widely: both bactrian and dromedary camels have been recorded as giving 5 000 litres per lactation but this, at present, is exceptional. Under desert conditions the average yield is probably 1 200 to 1 600 litres per lactation and, when well-fed, up to 3 000 litres. The milk is credited with certain tonic and medicinal properties and is widely believed to confer strength, virility and longevity. It is popular and highly acceptable. The late, greatly respected King Khaled of Saudi Arabia was never without camel milk: even on his travels a refrigerated supply ensured his daily ration. A 40-camel milking parlour, with the world's first automatic camel milking plant was successfully established at the Royal Palace at Riyadh in 1978 and marked a great advance in camel husbandry.

Over the past 80 years or more, the veterinary profession has been responsible for great improvements in camel welfare, husbandry and management, and names like those of Cross, Curasson, Donatien and Leese feature in the classic literature of their times. Faulkner, the FAO veterinarian, considering the future of the camel, wrote "The dromedary is adapted for the life in hot, dry desert conditions; eye lashes that protect the eyes from wind-blown sand, slit nostrils that can be compressed, thickened lips to enable it to browse on thorny trees and coarse plants, flat padded feet ideal for sand but tolerant of shingle and rough ground, possession of a hump with a reserve of fat and the ability to conserve body water, it tolerates a high degree of dehydration and can control excretion rates enabling it to maintain life and to work on a limited supply of water for longer periods than any other transport animal. In their feeding habits camels prefer to browse on trees, bushes and shrubs such as camel-thorn, acacia and salt bush which other domestic livestock will not touch".
Many veterinarians participated in the IPS Workshop and much attention was given to the important question of disease control, the disease situation being summarized by Dr D. Richard of the Institute d'Elevage et de Médecine Veterinaire des Pays Tropicaux, Maisons-Alfort, France. It is widely believed and often repeated that the camel is seldom ill and when it is, it is going to die. There may be an element of truth in this statement for normally the camel is a hardy and healthy animal which, even in disease, is uncomplaining and almost asymptomatic. As Dr Mukasa-Mugerwa of the International Livestock Centre for Africa has pointed out in his recently published biographical review, dromedaries apparently suffer from fewer diseases than other domestic livestock and epidemics are rare. The knowledge exists of how to control all the main diseases of camels, except for certain parasitic and other conditions in the South American group which require further investigation. Trypanosomiasis - in regions where the causal agents are found - internal parasitism, sarcoptic mange (a zoonosis) and camel pox are among the more serious and costly conditions encountered and they are limiting factors to production. Much further research in the field of cameldid health is needed, especially into the means of control of disease by vaccines, chemotherapeutics and anthelmintics. An urgent requirement is a renewal of the support of the pharmaceutical industry, for example in the production of new and more effective trypanocides, the attack upon drug resistance and the production of a vaccine against camel pox. As things are at present there is not much profit though there may be much prestige in producing medicaments for the benefit of a handful of nomads. The situation, however, is changing and the trend is toward intensive rather than extensive husbandry.

The logistical question of getting the right medication or biological to the animal at the right time, in the correct dose and in prime condition, presents a difficult but not insuperable problem. Highly mobile and
well-equipped veterinary services are needed wherever there are camelid populations. Selected lay attendants should be given training in animal health control and supplied with medicaments and a first aid kit on the pattern of the "barefoot vets" of China.

The study of animal behaviour, a biological science in its own right, has contributed much to the existing knowledge of the camelids and to their welfare. In this volume we are privileged to include a paper by the late Dr Hilde Gauthier-Pilters who, although in poor health at the time, participated actively in the workshop and later extensively amended and extended her contribution. A camel research scientist from her earliest professional days, her first recorded publication was in 1958 and the latest (with A.I. Dagg, The camel: its Evolution, Ecology, Behaviour and Relationship to Man) in 1981. She was an ethologist and ecologist of great ability, profundity and pragmatism, who made an outstanding contribution to our knowledge of dromedary biology through her remarkable powers of penetrating but objective observation, meticulous recording and concise perspicacious reporting.
SECTION A

SPECIES, BREEDS, TRADITION AND STATUS
ORIGINS, EVOLUTION AND DISTRIBUTION OF DOMESTIC CAMELS

I.L. Mason

Summary

The Camelidae evolved in North America. From there they migrated into Asia during the Ice Ages. Those remaining behind moved south to develop into the wild guanaco and vicuna (and later the domestic llama and alpaca) of South America, or they became extinct. The wild camels colonized their new home as far as Eastern Europe. They crossed into Africa and extended as far west as the Atlantic Coast and as far south as northern Tanzania, but died out before domestication. The one-humped camel was probably first domesticated about 3000 B.C. in southern Arabia. From there it spread throughout its present range in the desert and semi-desert areas of northern Africa and the Middle East. The two-humped camel was probably domesticated on the borders of Iran and Turkmenistan, again about 3000 B.C. From there it spread west as far as the Crimea, north as far as southern Siberia and east as far as Mongolia and northern China. In Turkey, Iran, Turkmenistan, Afghanistan and the northwest of the Indian subcontinent it was later displaced by the one-humped variety.

Introduction to Australia in the 19th century has led to a large population of feral one-humped camels in the arid interior of that continent, the only known feral camel population in the world.

Introduction

Camels belong to the family Camelidae in the ruminant suborder Tylopoda of the order Artiodactyla (even-toed Ungulates). The other ruminant families are Giraffidae (giraffes and okapi), Cervidae (deer) and Bovidae
(cattle, buffalo, sheep, goats, antelope). The Camelidae are usually separated from the other ruminants into the group Tylopoda (=pad-footed) because they walk on pads at the end of the digits instead of on the sole of the hoof (the hoofs are reduced to claw-like toes projecting beyond the pad). The camelidae also differ from other ruminants in not having horns or antlers. They are unique among mammals in the oval shape of their red blood corpuscles.

In the New World the Camelidae are represented by two wild species in the high Andes. The vicuna (Vicugna vicugna) is now very rare and restricted to the highlands of Peru and Bolivia. The guanaco (Lama guanaco) now has a discontinuous distribution from Bolivia to Tierra del Fuego. From it have been developed two domestic animals - the llama (Lama glama) and the alpaca (Lama pacos) now found in the high Andes of Peru and Bolivia. The South American Camelidae were formerly termed "Auchenidae" (Gk. aukhen = neck) because of their long necks. In addition to their general conformation they share with Old World camels their amazing water economy which is associated with their distribution in a dry environment. They also have the same chromosome number - 74 (Hsu and Benirschke, 1967, 1974). However, New World Camelidae do not have humps.

In the Old World there are two types of camel, the one-humped and the two-humped. Linnaeus placed these in separate species, Camelus dromedarius and Camelus bactrianus, or dromedary camel and bactrian camel. In this paper the terms one-humped camel and two-humped camel will be used, for several reasons. To retain the Latin specific epithets is not appropriate since the two types apparently cross readily and the crosses are fertile in both sexes.

It is true that Grzimek (1972) writes "...hybrids are often larger and stronger than their parents, yet they are either sterile when bred to each other or else
produce only weak offspring" while Gray (1977) writes "According to Wender, male hybrids are sterile". However Epstein (1971) and Bulliet (1975), while confirming the hybrid vigour, quote evidence from U.S.S.R. and elsewhere that hybrids of both sexes are completely fertile. Zeuner (1963) also accepted the fact of hybrid fertility but did not on that account think it necessary to put in the same species types which differ so strikingly and have been separate for so long. In addition to the obvious difference the two-humped variety differs from the one-humped in being woollier, shorter in the leg and darker in colour. It is also adapted to the low winter temperature of Central Asia while the one-humped type is the typical animal of the deserts of North Africa and the Middle East. There is a tradition that the gestation length of the one-humped camel is 12 months and that of the two-humped 13 months and Kenneth and Ritchie (1953) give some rather poor evidence to support it. The figures from zoos in Schmidt (1973) are 12 or 13 months for the one-humped and 13 for the two-humped.

Apart from the question of one species or two, it is questionable whether the Linnaean binomial is appropriate to a species which is domestic rather than wild. (The one-humped is known only as a domestic animal, the two-humped almost entirely so). The terms C. ferus forma dromedarius and C. ferus forma bactriana are used by Schmidt (1973) but the description "ferus" seems inappropriate to tame animals.

The traditional terms "dromedary" and bactrian camel" are also unsatisfactory. "Dromedary" is really an adjective and should be "dromedary camel". Furthermore the word comes from the Greek "dromos" = road, and is correctly applied only to the riding or racing camel. The two-humped type was called "Bactrian" when it was believed to come from Baktria (Balkh). But this area (the Oxus river valley in northern Afghanistan) was certainly not the place of origin of the two-humped camel and now it is inhabited entirely by one-humped.
Evolution of the Camelidae

The fossil record shows that the early evolution of the camel family took place entirely in North America. The earliest known ancestor, Protylopus, lived in the Upper Eocene period; it was no bigger than a hare. Remains of animals of increasing size from later periods have been allocated to a number of genera culminating in the appearance of Camelus during the Pleistocene period (which began half a million years ago). During one of the Ice Ages, a solid bridge between Alaska and Siberia closed the Bering Straits and enabled the early camels to spread into Asia. Fossils of different species are found across the dry centre of the continent and into Eastern Europe (southern Russia and Romania). Some of these early camels migrated through the Middle East and across North Africa as far west as the Atlantic, and as far south as northern Tanzania (Gentry and Gentry, 1969).

In the meantime the camel family died out completely in North America. However, some camelids migrated to South America and became the ancestors of the guanaco and vicuña. These species, of course, have no humps and this fact raises the question - did the early camels which moved from North America to Asia have humps and, if so, of what type? In theory, it is possible that the camel's fat hump, like that of the zebu and like the fat store of the fat-tailed sheep, was a product of domestication and was not present in the wild animal. However, this is unlikely since a recent discovery by A.P. Okladnikov (mentioned by Friese, 1975), of rock drawings in Choit-Zenker cave, Mongolia, shows a typical two-humped camel from Magdalenian times (10 000 - 5 000 B.C.) long before domestication could have taken place.

It seems possible then that the first camels in Asia and Africa were two-humped and that the single hump was developed when the camel was becoming adapted to the hot dry conditions of the Middle East and North
Africa. Possibly the single hump offered a smaller surface area for water loss by sweating (Bulliet, 1975). Alternatively the first Camelus may have had no hump or a single flat layer of fat along the back and from this the two hump types may have developed independently. As indicated above the palaeontological record in North Africa gives no clue as to the nature of the hump although Zeuner (1963) lists several sited in Maghreb where remains of wild "dromedary" (or a closely related species, C. tomasi) are found in association with Palaeolithic man in Acheulian and Mousterian times (80 000 – 15 000 B.C.).

Wild camels appear to have survived in North Africa into the Neolithic period. However, their complete absence from the Saharan rock drawings and from the writings and tomb and temple paintings of dynastic Egypt indicates that by historical times wild camels had died out in North Africa. Bulliet (1975) suggests that the prehistoric camel lived in a bushy semi-arid environment, that it had no defence against predators such as lions and was unable to hide from them in the emerging desert. It became extinct in the Sahara and its surroundings before 3 000 B.C.

The wild camel was also becoming rare in the Middle East at this time. However, as late as Roman times (c. 170 – 100 B.C.) wild camels were observed in South Arabia (where the higher rainfall and absence of predators aided their survival). This is the most probable area of their domestication.

There is much less evidence available about the history of the wild camel in Central Asia - the ancestor of the two-humped domestic type. Probably at one time it was present from southeast Russia to northeast China. Today the wild two-humped camel occurs only in the trans-Altai Gobi desert on the border of Mongolia and China (Bannikov, 1975). Wild camels were first reported to the west by Przewalski in 1876 when they had a conti-
nuous distribution between the Tarim basin and the Mongolian Altai. Since then their numbers have declined and their distribution has become discontinuous. FAO (1977) estimated the number in Mongolia at 400 - 700. A reserve was established in 1975.

These wild camels differ from the neighbouring domestic ones in their more slender build, shorter hair, smaller feet and smaller, more erect humps. (A domestic two-humped camel often has flaccid humps flopping to one side). Doubts have been cast on the status of these camels as wild animals; it has been suggested that, in fact, they may be feral. However, the general view now is that they are true wild animals although they may have been joined by domestic escapees. The rock drawings of Okladnikov confirm the presence of similar wild camels in the area prior to domestication, and as late as the 1st century B.C. the hunting of wild camels is reported from the northern frontier of China (Epstein, 1971).

Domestication and dispersal of the one-humped camel

As we have seen, southern Arabia is the last place in which wild one-humped camels have been observed and it is the most likely place for their domestication. The time was about 3 000 B.C. Zeuner (1963) and Epstein (1971) give central Arabia as an alternative but Bulliet (1975) points out that the central desert would have been much too dry for the survival of prospective herders before they had the domestic camel at their disposal. He suggests that domestication was effected by an unknown pre-Semitic hunting and fishing people who tamed the camel for milk during the period 3 000 - 2 500 B.C. in the region of Hadhramaut, Mahrah and Dhufar (now the northeast of the Yemen Democratic Republic and the southwest of Oman). Epstein (1971) concludes that the time was the 4th millenium B.C., the place "a remote part of the Arabian peninsula", the purpose meat and later milk, and the method the incorpora-
tion of young camels into domestic cattle herds. This attribution of the event to a Semitic people may be anachronistic because they did not arrive in southern Arabia until about 1600 B.C. Zeuner (1963) suggests a date of 2900 - 1900 B.C.

The evidence for the domestication of the one-humped camel in Arabia (whether southern or central) is circumstantial rather than direct. No camel fossils have been found in Arabia and the archaeological record (at least until recently) does not go back further than the 9th century B.C. In the rock art of central Arabia, camels are copiously represented as game and as riding animals, but the first direct evidence for the domestic dromedary in south Arabia (Hadhramaut) is in the 6th century B.C.

The circumstantial evidence is, nevertheless, very strong and is summarized by Epstein (1971). The earliest archaeological records of the domesticated one-humped camel come from Egypt, Mesopotamia and Palestine, Arabia's immediate neighbours. The camel was used in the incense trade of Southern Arabia into Palestine, Syria and the Eastern desert of Egypt. In Sumerian cuneiform the one-humped camel was called "beast of the sea (land)" which suggests the Gulf coast of Arabia. The Assyrians used the Semitic word "gammalu" for the one-humped camel to distinguish it from the two-humped. Camels were sacrificial animals in the pre-Islamic Arabia and camel sacrifices continued in some parts of Arabia into Islamic times. In practically all early historical records on one-humped camels (whether Biblical, Assyrian, Greek or Roman), the animal is connected with Semitic and especially Arab tribes. In addition Bulliet (1975) argues that the expression "ship of the desert" must derive from the seafaring people of southern Arabia and describes the legendary wild camels (ḫūsh) in southern Arabia from which the Mahrah and Omani breeds are reputed to be derived.

More recently the author saw in the Abu Dhabi
museum at Al Ain a rock drawing of a camel from the prehistoric pre-Semitic site on the island of Umm an Nar which was dated to 2700 B.C. (This is 1000 km north of the Hadhramaut, across the desert of the Empty Quarter). It is not known whether this specimen was domestic or wild but it indicates that camels were present at that time and were sufficiently important to be used in art.

In this connection it should be pointed out that Bulliet (1975) in note 32, page 286 writes, without comment: "In Arabia a figure of a camel was found in low relief on a stone slab that also bore a depiction of a humpless bull. The site of this find in eastern Arabia is dated to the third millennium B.C., Geoffrey Bibby, Looking for Dilmun (New York: Knopf, 1969) p. 304."

From southern Arabia Bulliet (1975) considers that camels entered the Horn of Africa (present-day Somalia) in connection with the sea-borne incense trade during the millenium from 2500 to 1500 B.C. This was at the same time as the short-horned cattle but before the zebu.

There is almost no archaeological evidence of tame camels in northern Arabia, Palestine, Syria or Egypt before 1100 B.C. There are occasional references to camels, a few seals, pots and figurines and a famous camel-hair cord found in the Fayum of Egypt, from the period 2500 - 1400 B.C., but all these can be explained as introductions of animals or artifacts by traders from the south. There is no evidence that camels were bred in northern Arabia or north thereof during this period.

The references to camels in the Bible stories of Abraham and his immediate descendants (Isaac, Jacob and Joseph) have been often quoted to prove the regular use of camels in northern Arabia during the 19th and 18th centuries B.C. While the reputed gift of camels from Pharaoh to Abraham must be a later insertion, the other references show only that camels were present in the
Palestine - Jordan area in small numbers long before they were bred or herded there. This is confirmed by the presence of camel bones at various archaeological sites in Palestine dated to the 18th to 16th centuries B.C. In Mesopotamia occasional representations of one-humped camels (as well as two-humped) are known from an early period (3 000 - 1 200 B.C.). However, the camel was rare in these countries until the Aramaean invasion from central Arabia between the 16th and 13th centuries B.C. In the 11th century B.C. the Aribi introduced camel nomadism into the desert lands formerly occupied by the Aramaeans. But the first great invasion of camel nomads was that of the Midianites (= Ishmaelites) who poured into Palestine and Syria from northwest Arabia about 1 100 B.C. "Their camels were without number" (Judges 6, v.5).

In Arabia and the Middle East camels were thus available in quantity, certainly by 700 B.C. But the camel breeders were nomads, more or less outcasts, and the camel did not become an important animal until their breeders acquired military, political and economic power, i.e. until the rise of the Arabs. Bullet (1975) attributes this transformation largely to the invention of the "North Arabian" saddle in the period 500 - 100 B.C. This has saddle bows in front and behind the hump connected by wooden crosspieces along the sides. This arrangement enables the rider to sit on top of the hump while being supported firmly on the animal's backbone. (The "South Arabian" saddle, by contrast, was behind the hump). The camel-borne warrior seated on a North Arabian saddle was able to seize control of the caravan trade and hence the camel breeders became integrated into the economy.

The change in status of the camel herders led to the realization that the pack camel was economically more efficient than the mule or the ox cart. As a result the use of wheeled vehicles was abandoned during the period 300 - 600 A.D. over the whole area from Morocco to Afghanistan. Vehicular transport returned only with
the improved cart and carriage technology, better roads, and mechanization of the 19th and 20th centuries.

Turning now to North Africa, there are two possible routes of entry - along the coast from Egypt or along the southern fringe of the desert from the Sudan. Bulliet (1975) presents convincing evidence that the latter was the more important route. The cultivated Delta of Egypt would be a biological and sociological barrier to a desert animal and anyway the camel was almost unknown in ancient Egypt. The southern route across the Red Sea is more likely and indeed there were trade routes from the Red Sea to the Nile in the 3rd century B.C. From the Eastern desert camels moved south to the Sudan and from Upper Egypt and northern Sudan they probably spread westwards via the south Saharan highlands - Ennedi - Tibesti - Tassili - Ahaggar - Adrar of the Ifoghas. Camels are represented on Saharan petroglyphs of the late or camelline period. These are apparently difficult to date but Zeuner (1963) suggested 1 500 - 500 B.C. (Bulliet (1975) uses the evolution of saddle design to support his case.) They then slowly worked their way northwards and were encountered by the Romans in Tripolitania and Tunisia in the 2nd century B.C. There they were changed from a pack to a draft animal.

In late Roman times (after the 3rd century A.D.) large numbers of camels were introduced into North Africa through Egypt but it was not until the Moslem Arab conquest of Egypt in the 7th, and the great invasions of the 11th centuries that the camel in North Africa reached the numbers and importance that it has maintained until recently.

Domestication and dispersal of the two-humped camel

Although the wild two-humped camel now occurs only in Mongolia and Sinkiang it was formerly distributed as far east as southern Russia and as far south as Iran
and Afghanistan. It was not necessarily first domesti-
cated in its present habitat. In fact it would be
expected to survive where it had least contact with man
and to be domesticated where it had most. Furthermore
the camel was not known in China until the end of the
4th century B.C. which seems to preclude a domestica-
tion site on her borders.

Zeuner (1963) and Epstein (1971) report that camel
remains have been found in northern Iran and southern
Turkmenistan dating from about 3 000 B.C. but there is
no absolute proof that those remains were from two-
humped domesticated animals. However, Bulliet (1975)
writes: "In the light of recent archaeological disco-
veries it is becoming increasingly apparent that the
two-humped camel was actually domesticated in what is
today the border region between the northeastern Iranian
province of Khurasan and Soviet Turkmenistan. -- several
archaeological sites in Turkmenistan have yielded camel
bones and clay models of wagons in contexts dated
2 500 - 2 000 B.C. and 2 000 - 1 600 B.C. Other
excavations in the eastern Iranian province of Sistan
have turned up a clay jar filled with camel dung and
fragments of camel's hair fabric from the same period.
---- Traces of camels datable to before 1 500 B.C.
have not been found elsewhere in Soviet Central Asia,
so there is no indication that domestication reached
Turkmenistan from the north or east; but the associa-
tion of camels with wagons suggests a rather advanced
stage of domestication. It is entirely possible,
therefore, that the date of domestication may reach
back several centuries before 2 500 B.C."

The above-mentioned models do not exhibit humps
but the geographical, linguistic and social evidence
makes it certain that two-humped animals were involved.
To explain the paucity of camel bones at archaeological
sites, Bulliet (1975) suggests that at the time of its
domestication the two-humped camel was a rare species
on the brink of extinction. It may have been domesti-
cated because its large size and strength made it
attractive as a draught animal.
From its place of first domestication it had spread to the south Urals and northern Kazakhstan by 1700 - 1200 B.C., to western Siberia by the 10th century B.C., to the Ukraine by the 9th century B.C. and to China by about 300 B.C. It spread over all parts of the Iranian plateau except the Caspian shores and the Indian ocean coasts. It was known sporadically in Mesopotamia as early as the 2nd millennium B.C. It also spread to north, east and west Afghanistan and it entered the Indus valley with the Aryans.

The silk route from China through Central Asia and northern Iran to Baghdad was first operated with two-humped camels. In Mesopotamia they encountered one-humped camels and were crossed. The hybrids proved superior to the two-humped animals and replaced them on the silk route, at least as far north as the Oxus river. This crossbreeding started in Parthian times (2nd and 1st centuries B.C.) and was given further impetus by the spread of the Arabs into Iran and Central Asia. At some stage a long-haired, cold-resistant, breed of one-humped camel developed which was adapted to the Iranian plateau. It was therefore able to displace the two-humped camel there as well as in Turkmenistan and Afghanistan. The one-humped camel also replaced the two-humped in Anatolia and in Pakistan and India, and spread, alongside the two-humped, into the North Caucasus and southern Russia and into Russian Central Asia as far north as the Aral Sea. There are also a few one-humped camels as far east as Sinkiang.

Present distribution and use

The present-day distribution of one- and two-humped types resulting from these historical processes is shown in Figure 1. Although the exact boundaries are only approximate, especially in the U.S.S.R., it is striking how closely the limit of the camel-breeding area follows the isohyet for 50 cm of rain. It is also clear that two-humped camels are not found where the mean annual temperature is above 21°C.
Of course camels are not uniformly distributed over the areas shaded. Table 1 gives some idea of their density in different regions. Because of the notorious unreliability of livestock statistics, and of camel statistics in particular, country figures have been rounded to the nearest 100,000.

On account of this rounding the regional totals do not always agree with the sum of the country figures. In spite of these inadequacies in the figures there can be no doubt that the majority of the world's camels are to be found in northeast Africa and the next largest concentration is in northwest India-Pakistan-Afghanistan. In both these regions, and also in West Africa, numbers appear to be increasing. The countries where numbers have decreased most dramatically are: Morocco, Libya, Iraq, Saudi Arabia, Iran, Syria and Turkey. In the last 30 years total numbers in these countries have declined from over 2 million to less than 1/2 million but even this decline has not significantly affected world totals.

As for two-humped camels it is safe to assume that numbers are decreasing slowly in all three countries which they inhabit.
### Table 1: World numbers of camels (millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>One-humped</th>
<th>Two-humped</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1978</td>
<td>1949/50</td>
</tr>
<tr>
<td>1978</td>
<td>1969/71</td>
<td></td>
</tr>
<tr>
<td>North East Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somalia</td>
<td>5.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Sudan</td>
<td>2.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Kenya</td>
<td>0.6</td>
<td>(0.4)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9.9</strong></td>
<td><strong>5.4</strong></td>
</tr>
<tr>
<td>West Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mauritania</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Chad</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Niger</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Mali</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Western Sahara,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria, Senegal,</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Upper Volta</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.8</strong></td>
<td><strong>0.6</strong></td>
</tr>
<tr>
<td>North Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tunisia</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Algeria</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Egypt</td>
<td>0.1</td>
<td>(0.1)</td>
</tr>
<tr>
<td>Libya</td>
<td>0.1</td>
<td>(0.3)</td>
</tr>
<tr>
<td>Morocco</td>
<td>0.02</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.5</strong></td>
<td><strong>1.0</strong></td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>0.3</td>
<td>(0.3)</td>
</tr>
<tr>
<td>Iraq</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Iran</td>
<td>0.03</td>
<td>0.6</td>
</tr>
<tr>
<td>South Arabian and States</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>East Mediterranean countries</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2.9</strong></td>
<td><strong>3.2</strong></td>
</tr>
</tbody>
</table>

**Source:** FAO Production Yearbook No. 16 (1962) and No. 32 (1978) (figures in brackets are estimates).

1) In fact some camels in the U.S.S.R. are one-humped but the majority are two-humped.

2) According to Dong (this volume) this figure should be 0.6.
History has had a large hand in moulding the uses to which camels are put in different regions. The two-humped camel was apparently first domesticated as a draught animal and it is still used as draught (and pack) animal throughout its range. The one-humped, on the other hand, is primarily a pack and riding animal and it is used for draught only in four widely separated areas (Bulliet, 1975). These are: 1. The Indus valley (Pakistan) and northwest India; 2. Cape Bon peninsula, northeast Tunisia; 3. Mazagan (El-Jadida) on the Atlantic coast of Morocco; and 4. Aden in the Yemen Democratic Republic. In India and Pakistan the two-humped camel pre-dated the one-humped and the function of pulling carts and ploughs was transferred directly from the one to the other when the one-humped camel started entering in numbers after 1 000 A.D. (with the Baluchis). The idea of draught camels was introduced from British India to British Aden. The use in Tunisia (to which may be related that in Morocco) is apparently a lineal descendant from Roman times. Tunisia (like Turkey) is thus an area where the wheel never disappeared.

One-humped camels may be divided, according to habitat, into mountain and lowland types. The former is small, compact and coarse-boned. The sole of the foot is very hard; a long fur may develop in winter. It is a pack animal. The lowland camel is larger and the foot tends to be softer. The lowland group is subdivided into the slender desert or riding breeds and the larger more compact riverine or baggage camels. Alternatively the one-humped camel may be divided into baggage and riding types and the former subdivided into hill and plains sub-types. Two famous breeds of riding camel are the Mēhari of the Sahara and the Mahri of Pakistan. Both names may derive from Mahra in southern Arabia - the putative place of first domestication.

Camels are milked in many countries, but in Somalia their milk is of prime importance. They are used as pack animals, but rarely for riding.
Camels are usually slaughtered for meat at the end of their working lives (or on ceremonial occasions) but in some places, for example Somalia, Sudan and northern Kenya, many camels are now kept solely for meat. Much of this production is exported to Egypt, Libya and other oil-producing countries.

Camel flesh is taboo among various non-Moslem peoples of the Near East. These include the Jews, the Zoroastrians of Iran, the Mandaeans of Iraq and Iran, the Nosairis of Syria and the Christian Copts of Egypt and Ethiopia (Simoons, 1961).

Recent introductions

Since camels became known to Europeans many attempts have been made to implant them in regions outside their original range (see Cauvet, 1925; Bulliet, 1975). Only two of these introductions - to the Canary Islands and to Australia - met with any lasting success. The Canary Island population was introduced from Morocco after the islands had been conquered for Spain in 1402. They are still bred there and are used in agriculture and as beasts of burden. The next experiment was made by one of the Medicis who in 1622 imported camels from Tunisia and established a stud near Pisa in Northern Italy. This lasted for over 300 years and grew to number about 200 head but the animals were eventually eaten by the Germans during World War II.

The Moors brought camels to Spain but they later died out. Attempts to re-establish breeding herds during the 18th and 19th centuries were failures. Other experimental importations into Europe, the Caribbean, and South America in the 19th century were just as unsuccessful. There was no economic role for camels and in almost every case the environment was unsuitable. However, in one case, namely the dry plateau of northeast Brazil, the climate was suitable. Nevertheless nothing more was heard of 14 camels imported from Algeria to
Ceará in 1859. Provided there are no disease hazards this is an introduction which might be worth repeating on a larger, but strictly experimental, scale in order to exploit the thorny scrub and increase the meat supply for a needy population.

Attempts by the British, Germans and Portuguese to establish camels from north Africa in the semi-arid parts of their colonies in southern Africa were also biologically sound. But they came too late (early 20th century) to be able to compete successfully with motor transport. Nevertheless, according to McKnight (1969), a handful of semi-feral camels were still present in South West Africa (Namibia) when he wrote.

Plans to use camels in the desert and semi-desert areas between Texas and California were nearly successful but the experiment was interrupted by the Civil War. In 1856, one-humped camels (78 in all) were imported to a US Army breeding farm in Texas. Although they were successfully used in surveying a new road from New Mexico to California, government policy changed and in 1866 the remaining animals were sold.

The big camel success story was in Australia. McKnight (1969), summarizes it as follows:

"Australia contains the second largest expanse of arid and semi-arid lands in the world, which explains the relative enthusiasm with which imported camels were greeted by early explorers and settlers. By the middle of the nineteenth century camels were being brought to two Australian colonies from British India. Hundreds of 'Afghan' camel drivers accompanied the imported beasts, and within a relatively short time camel teams had become essential suppliers to outback mining communities and remote pastoral stations, as well as contributing significantly to inland exploration and the construction of such diverse projects as the Overland Telegraph Line and the Transcontinental Railway."

"Camels continued to be useful for the first third of the twentieth century, reaching a
peak population of some 20,000 by about 1920. During the next two decades the advent of motor-cars and trucks began to make camels redundant, and many of the animals were turned out to fend for themselves. They took readily to a feral existence, and large populations of 'wild' camels built up throughout much of central Australia."

The first successful imports were in 1860 and 1866, to South Australia. The success of these, and later, imports was largely due to the camel drivers who came with their animals; although called "Afghans" they were chiefly Baluchis. "Even today", writes McKnight (1969), "there are a few domesticated camels left in Australia". About 100 were on nine cattle stations, chiefly employed in hauling supplies to cattle mustering crews. These are bound shortly to disappear. On the other hand, those owned and used by Aborigenes as pack and transport animals (about 400, mostly in the area to the south and southwest of Alice Springs) probably have an important future and the number of Aboriginal-owned camels may well increase. This inclusion of camels into the way of life of a primitive people who previously had no domestic animals (with the occasional exception of dogs, pigs and poultry) represents a major cultural innovation.

When McKnight wrote (1969), he estimated the number of feral camels at 15,000 - 20,000 ranging over an extensive area in the centre and west of the continent with the greatest concentration in and around the Simpson Desert. Although they feed mostly on trees and shrubs and therefore do not compete with cattle for feed, they are considered to be notorious fence destroyers and are persecuted by pastoralists and vermin control officers. Numbers are therefore declining.

McKnight (1969) points out that, because of its adaptation to desert life, over most of its range the feral camel is the only large animal present. Even in drought years, camels are able to maintain their condition when other ungulates suffer and often die.
He recommends studying the possibility of exploiting feral camels for profit. If a market for their meat were developed, they could, like buffaloes in the Northern Territory, be regularly mustered and shot.

Even in the original home of the one-humped camel, Arabia, where until recently they have been too valuable to be allowed to run wild, it may be that the future of the camel lies in the exploitation of meat from feral or semi-feral animals.

REFERENCES

Bannikov, A.G., 1975 The wild camel or Khavtagai. Priroda, No. 2, 62-69


Zeuner, F.E. 1963 A history of domesticated animals. London: Hutchinson
THE DROMEDARY OF THE SUDAN

F.M. El Amin

Introduction

The camel is one of the most neglected of domestic animals. The majority of studies have been mainly on its anatomical features and physiological adaptations to desert conditions. Only limited studies have been made on husbandry requirements and the economic benefits to owners. The camel lives and exploits areas that are presently affected by desert encroachment which will endanger the species and the livelihood of camel owners.

History

The present day one-humped dromedary, which is the only type found in Africa, is believed to have evolved in southwest Asia and the Arabian peninsula. This was confirmed by the discovery of remains dating back to the Middle Bronze Age (about 1800 B.C.) in old Palestine. From there, it found its way to its present habitats in India and in North Africa.

The history of the dromedary camel in the Sudan is even more obscure. It is believed to have entered the Sudan from Egypt. A specimen of camel hair rope of the Old Kingdom was found at Fayum in Upper Egypt dating about 2980 - 2475 B.C., indicating that the animal had moved south by that period. In Sudan, the oldest evidence is a bronze figure of a camel with a saddle found at Meroe and estimated to date to between 25 - 15 B.C. (Addison, 1934; Robinson, 1936). Despite the large numbers and their adaptation to the environmental conditions, camels are not indigenous to the Sudan.
Habitat, distribution and numbers of camels in Sudan

The distribution areas of camels in the Sudan are mainly in the arid and semi-arid parts of the country north of about 13° N. These are the areas where rainfall is less than 350 mm. and, because of the drought in the northern parts of the country, the areas extend south of this line. However, migration to the southern part of the country is limited by diseases such as trypanosomiasis (Surra or Gufar) and the unsuitability of the clay soils.

It has always been difficult to make reasonable estimates of camel numbers in the world, mainly because camels exist in desert areas with difficult accessibility. The estimated world total population (FAO 1980) is 16 621 000, of which 2 500 000 are in Sudan.

Sudan has one of the largest national herds in the world, located in the northern provinces (Table 1).

Camel types in the Sudan

In the Sudan, camels are owned by tribes that inhabit the dry semi-desert areas. Because of its limited distribution and numbers, the camel has undergone very little variation and there has been no development into individual differentiated breeds as is the case with other types of farm animals.

Camels in Sudan and elsewhere are classified as pack (heavy) and riding (light) types according to the function which they perform, and probably as a result of selection applied for these traits by the various camel-owning tribes. The riding camel has received more attention and has undergone intense selection. The following classification is based on conformation and tribal ownership.
1. The Sudanese pack camel

This is the heavy type which makes up the majority of the camels maintained by nomads.

   a. The Arab camel. This groups together several pack camel types mainly in northern Darfur and northern Kordofan provinces, bred by the Kababish (see Plate 1), Hamar, Kawahla, Zagawa, Maidob Shenabla and Zayadya nomads. The Arab camel is a sandy-grey, large, heavily built animal with a well developed hump. It has the widest distribution in the Sudan mainly due to its good performance as a work animal. A mature animal weighs about 400 - 500 kg and can carry about 275 kg over 25 - 30 km per day.

Table 1: Camel population in the various provinces 1976/77 (Ministry of Agriculture, Food & Natural Resources)

<table>
<thead>
<tr>
<th>Province</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Northern</td>
<td>107 977</td>
</tr>
<tr>
<td>2. Nile</td>
<td>59 058</td>
</tr>
<tr>
<td>3. Kassla</td>
<td>567 949</td>
</tr>
<tr>
<td>4. Red Sea</td>
<td>95 479</td>
</tr>
<tr>
<td>5. Khartoum</td>
<td>13 740</td>
</tr>
<tr>
<td>6. Blue Nile</td>
<td>37 787</td>
</tr>
<tr>
<td>7. Gezira</td>
<td>146 051</td>
</tr>
<tr>
<td>8. White Nile</td>
<td>77 877</td>
</tr>
<tr>
<td>9. N. Kordofan</td>
<td>851 587</td>
</tr>
<tr>
<td>10. S. Kordofan</td>
<td>1 798</td>
</tr>
<tr>
<td>11. N. Darfur</td>
<td>226 103</td>
</tr>
<tr>
<td>12. S. Darfur</td>
<td>142 083</td>
</tr>
<tr>
<td>13. W. Equatoria</td>
<td>-</td>
</tr>
<tr>
<td>14. E. Equatoria</td>
<td>28 430</td>
</tr>
<tr>
<td>15. Bahr El-Áazal</td>
<td>-</td>
</tr>
<tr>
<td>16. Upper Nile</td>
<td>4 922</td>
</tr>
<tr>
<td>17. El Buhayrat</td>
<td>-</td>
</tr>
<tr>
<td>18. Jonglei</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2 360 862</td>
</tr>
</tbody>
</table>
Plate 1: Meat type (Kababish) she-camel and calf

Plate 2: Meat type (Shukrya) camel from eastern Sudan

Plate 3: Racing camel - Anafi type
b. The Rashaidi camel is pinkish-red in colour, slightly shorter than the Arab and less numerous. Rashaidi camels are herded mainly by the Rashaida nomads of eastern Sudan who recently migrated from Saudi Arabia. Some Rashaidi camels are owned by the people who share the same ecological zone like the Shukrya (see Plate 2) and Batahyn.

2. The Sudanese riding camel

This is the type which was developed for riding and is selected for speed. It is lighter in bodyweight. It is mainly bred in the north-east of the country.

a. The Anafi camel is the fastest. It has long legs, light body colour, a small hump and a long narrow head. It has a very fast pace over short distances. Over distances of more than 40 kilometers, the animal lacks the stamina of the other types. (Plate 3)

b. The Bishari camel. This is the name designating the group of animals owned by the nomads of Eastern Sudan like the Bisharin, Amarar, Hadendows and Beni Amir. Together they form the Beia group. The animals are stronger and slightly larger than the Anafi type. It is a general purpose mount with a better conformation and a well developed neck.

Various camel-owning nomadic groups have developed riding camels from crosses of Bishari or Anafi camels with their local strains.

General characteristics of the one-humped camel.

In the history of the evolution of the species, the dromedary has lost all of its toes except two. These are joined together by a large horny sole that confers a great advantage on sandy soils. The sole acts as a cushion which absorbs the heavy weight of the body and contributes to a very silent tread.
There are various horny skin pads which come in contact with the ground when the animal is in the sitting position. The largest of these is below the sternum. The others are over the elbows, knees, stifles and hocks.

The nostrils are elongated slits and can be closed at will to prevent the entrance of sand. The upperlip of the camel is divided into two parts which facilitates browsing thorny bushes. It is also the most sensitive area of the animal which can be effectively controlled by grasping it.

The soft palate of the male is well developed. The mucosa of the buccal cavity is protruded as a balloon-like structure during the rutting season.

Camels differ from other ruminants in several respects. They lack a well defined omasum. The rumen, or first stomach, has two glandular sacs or diverticula. These used to be known as "water sacks" from the incorrect assumption that their function was to store water. The camel, like the horse, has no gall bladder.

The hump, which is a store of fat bound by fibrous tissue, is a reservoir of food which can be oxidized and used when needed. The fat is concentrated in the hump, instead of being distributed through the subcutaneous layers to allow the process of radiation for cooling purposes (Cloudsley-Thompson, 1969).

The most peculiar trait of the camel is its great tolerance to heat and water deprivation. Camels can lose up to 30 percent of their body water and still remain in good health (Schmidt-Nielsen, 1964). They compensate for water loss by consuming large quantities of water at one time (about 100 litres). This causes a dilution of blood and other body fluids which can not be tolerated by other animals: the erythrocytes of the camel can swell to twice their normal size without rupturing.
There are various means by which the camel econo-
mizes on water loss. The coarse hair on its back reduces
the solar radiation falling directly on the camel. The
animal has a wide range of temperature tolerance (about
70°C) which allows it to store heat during the day and
dissipate it at night. It has the capability of reducing
and concentrating urine and faeces so that very little
water is lost (Schmidt-Nielsen et al., 1956).

The pastoral system

Like other nomads, camel-owning tribes are continuously
on the move seeking grazing and water. Thus, for them,
nomadism per se is an ecological factor. In Western
Sudan, they travel from the north to the south of the
province, a distance of approximately 1 000 kilometers.
The various tribes have traditional migration routes
but the pattern of movement is generally similar. During
summer - between March and June - they return to their
home base (Dar), where water is obtainable from wells
and grazing is in the valleys (Wadis). Occasionally,
they move south and return to the home area when the
rains begin, remaining there for most of the rainy
season. In November they reach the Gizzu grazing land
of the North-West of Sudan (Asad, 1964).

The camel migration patterns in Eastern Sudan are
different from those of Western Sudan: the distances
travelled are shorter and the areas are not so arid.
The Shukrya and Rashaida move between the rivers Dindir,
Rahad and Atbara.

In recent years large mechanized agricultural irri-
gation schemes have modified these movements. Of special
importance is the long canal of the Rahad Scheme, which
provided a permanent water source for the animals. In
the canal areas north of the river Atbara the camel
movements take a north-south migratory route. They reach
the Atbara river in the south, passing on their way the
Gash Delta. They also utilize the winter grazing areas
of the Red Sea hills.
Reproduction

In species where the gestation period is lengthy and reproduction rates are low, reproductive traits have a special significance. The female camel has been assumed to be a seasonal breeder (Abdalla, 1965; Charnot, 1964; Yasin and Wahid, 1957; Matharu, 1966). But Musa (1969) has demonstrated that oestrus is exhibited by the female all the year round. However, Nawito et al (1967) have indicated that female camels in Egypt show seasonal variability in oestrus.

On the other hand, seasonality is manifest in the male camel, the reproductive behaviour being known as "rutting" or "heige" the season when male camels are sexually active. They exhibit specific behavioral patterns that are characteristic of readiness for mating, mainly during the rainy season between June and October. During this period male-camels become over excited. They evert the soft palate making loud noises and continuously grinding the teeth. Saliva flows copiously. The animals are often aggressive and difficulty to handle. Their testes increase in size and there is frequent erection of the penis. The length of rutting season varies a great deal ranging on the average between two and four months depending on the nutritional status and age of the animal.

The signs of oestrus in the female camel are not so pronounced. The female becomes restless and shows swelling of the vulva accompanied by a discharge of mucous. Duration of oestrus is about 4 - 7 days (Musa, 1969; Nawito et al, 1967). The pattern of oestrus cycle, however, is not very clear. This is because in the Camelidae ovulation depends upon the stimulus produced by coitus (Fernandez-Baca, 1978; Nawito et al, 1967). Nawito et al (1967) suggested the term "follicular wave" to describe the period between any two ovulations as indicated by acceptance of the male. This period ranges between 11 to 35 days with an average of 24 days. The follicular wave period is preceded by an anoestrus stage
of about 15 days during which the follicle reaches maturity and after which the female camel will be ready to accept the male. If copulation occurs, ovulation may take place 30 - 40 hours later, otherwise, the follicle is reabsorbed. Multiple ovulation is rare and twinning is exceptional in camels.

Female camels have characteristic behavioural patterns when they are in oestrus (Musa, 1969). A female in oestrus become restless and exhibits frequent urination. She tends to seek the male and stands to be mounted. The vulva becomes swollen with mucous discharge. Courtship is also indicated by the male sniffing along the neck. Copulation takes place when the female squats and the male mounts her facing in the same direction with all his weight on his hind legs. Mating takes on the average about 20 minutes.

The gestation length ranges between 360 and 390 days and the reproduction cycle takes two years. The calving percentage ranges between 35 and 45.

Males and females reach sexual maturity at about 3 years of age (Williamson and Payne, 1978). The lifespan of the dromedary is about 30 years. They continue to breed until they are about 20 years old.

In nomadic breeding herds usually one male is kept to about 50 females. There is a strict hierarchical dominance relationship between males established by fighting during the mating season. The dominant male usually has most of the matings.

Production

The production potential of the camel has received lamentably little attention. There are five main areas where camels can contribute: these are meat and milk production, work power and hair and hides by-products.
1. Meat production

In Sudan, wherever dromedaries are maintained, camel meat is consumed in large quantities. The following figures show the number of camels slaughtered in the various slaughter houses in Sudan.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>20 799</td>
</tr>
<tr>
<td>1971</td>
<td>25 726</td>
</tr>
<tr>
<td>1972</td>
<td>30 385</td>
</tr>
<tr>
<td>1973</td>
<td>27 340</td>
</tr>
<tr>
<td>1974</td>
<td>15 477</td>
</tr>
</tbody>
</table>

There are some traditional camel slaughtering towns such as El Obeid, Al Damar and Tanbul. Camels are usually slaughtered late in life which means that the meat is not of very good quality. The liver, however, is acceptable to most consumers and is the most expensive part per unit weight of the slaughtered animal.

The meat yield of the camel depends upon age and the condition of the animal before slaughter. Few studies on the meat characteristics of camels in the Sudan have been made. However, the dressing percentage can be expected to be within the range reported by Kuznetsov and Tretyakov (1972). They stated that the dressing percentage varies between 52.8 and 76.6 percent; fat between 0 and 4.8 percent, and bones between 15.9 and 38.1 percent. Weight at birth is between 30 and 40 kg while weaning weight is 150 to 180 kg, at about 1 1/2 years of age. Live-weight at maturity is 500 to 600 kg which is reached at 6 - 7 years of age. Thus, it can be seen that the camel is a slow grower. Studies are required to assess its growth curve and to determine the optimum slaughter weight.

The number of camels slaughtered in the Sudan is relatively small and is unlikely to increase dramatically because of the availability of such alternatives as mutton and beef. However, the bulk of the camel offtakes are exported to Egypt, Saudi Arabia and Libya. It is
estimated that over 60,000 camels go to Egypt on a quota system. In addition some camels are smuggled over the borders to both Egypt and Libya. It is estimated that about 10,000 camels reach Libya each year. This trade is carried out between November and April. Markets in Saudi Arabia now receive some camel exports from the Sudan: the market is well developed for the light racing camels.

Milk production

Camel milk is an important component of the diet of nomads in the Sudan. It is consumed by the owners and herders and is not exploited commercially. In the grazing areas of the Jizzu of north-western Sudan, camel herders live for long periods on camel milk alone (Tubiana and Tubiana, 1977).

Milk production in camels depends upon season, temperature and fodder supply (Knoess, 1977; Burgemeister, 1978).

Duration of the lactation period in Sudanese camels is variable, ranging between 10 - 12 months. Average milk production is 5 to 10 kg per day with a total lactation production of 1200 to 2600 kg.

Estimates of composition estimates (Table 2) show a high water and mineral content.

Table 2: Milk composition of 54 female camels sampled at 4 - 8 months post partum.

<table>
<thead>
<tr>
<th>Content</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>86.0 - 90.0</td>
</tr>
<tr>
<td>Protein</td>
<td>3.6 - 4.7</td>
</tr>
<tr>
<td>Fat</td>
<td>4.0 - 5.5</td>
</tr>
<tr>
<td>Ash</td>
<td>0.8 - 10</td>
</tr>
</tbody>
</table>
It is to be noted that milk is consumed raw (without boiling): it is not processed into cheese, butter or ghee.

Work performance

In Sudan, camels are used as draught animals, as baggage carriers and for riding. Riding is becoming less important with the wide introduction of motor vehicles in recent times. However, police, army and game patrols still use camels as mounts.

Camels are capable of transporting weights of between 150 and 300 kg over 25 kilometers per day. Heavier loads can be carried for short distances (Leese, 1979).

Gillespie (1962) has indicated that Sudanese riding camels cover 8 km per hour when trotting, and up to 32 km per hour when running. In a recent race in Saudi Arabia, a Sudanese camel won a race of 22 km in 45 minutes, i.e. at about 30 km per hour. When running at speed, the camel moves both front and back legs of the same side of the body at the same time (Cloudsley-Thompson, 1969). A camel cannot run continuously over very long distances.

Camel by-products

Camel hair is an important by-product for nomads. It is used for making robes, tents, saddle girths, blankets, clothing and carpets. A camel can produce between 0.5 - 1 kg of hair annually. Primitive production methods do not result in good quality leather but saddlery, whips and utensils are produced.

Conclusions

1. This brief review indicates the importance of the camel to the economy of camel-owning nomads and to the country at large.
2. It is emphasised that studies are needed on all aspects of camel husbandry, and especially basic investigations on breeding, feeding management, reproduction and behaviour.

3. The major emphasis should be given to the production of meat and milk from camels.

4. Cooperation in camel research is essential between such countries as Sudan, Libya, Egypt, Saudi Arabia, Somalia, Kenya, and other west African countries. Such cooperation might take the form of jointly operated research stations to conduct research and to train scientists.

REFERENCES


Addison 1934 A short guide to the Museum of Antiquities, Khartoum, National History Museum

Asad, T. 1964 The Kababish Arabs. London, C. Hurst


FAO 1980 Production Year Book, FAO, Rome


Matharu, B.S. 1966 Camel care. Indian Fmg., 16:19-22


Robinson, A.E. 1936 Between the third and sixth dynasty. Sudan Notes and Records, 19:47-69


Tubiana, M.J. and Tubiana, J., 1977. The Zaghoua from an ecological perspective (A. Balkema, Rotterdam)


A NOTE ON THE CAMELS OF THE AMAR'AR BEJA

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The authors worked in Sudan November 1979 to April 1980 and October to November 1980 on a research project of SAREC, the Swedish Agency for Research Cooperation with Developing Countries.

Amar'ar, the people and their location

In the Red Sea hill region of Sudan live a people usually referred to as Beja, but who in their Cushite language call themselves Bedawiet, a term which seems to be derived from Arabic and meaning "bedouins". The ancestors of the present Beja have been exploiting the same desert for thousands of years and were probably among the first African peoples to breed camels, around the time of Christ. Controlling the desert route from Red Sea ports to the upper Nile Valley, the Beja have since that time made good use of this beast, both for nourishment and as a riding or transport animal when acting as caravan traders or guides. Bullet (1975), however, suggests that the camel has been independently introduced to Africa twice. The camel economies further south on the Horn of Africa thus may have an older or separate origin from the camel rearing patterns found in the Sahara, to which the Beja are linked.

Far from being politically united, the Beja nation is made up of several rival confederations of land-controlling family groups, ideally patrilineally recruited but in practice with many aberrations of bilateral consanguinity. One of these confederations is the Amar'ar, exploiting the ranges between Port Sudan at the coast and Athbara on the Nile, but having tribal headquarters at Khor Ariab, north of Musmar (Map 1).

The Amar'ar territory is harsh. Living conditions are constrained by the failure or success of monoseasonal
Map 1: Directions of camel trade.
rains. Aulib, the inland plateau, experiences in most years one rainfall period during July-September, with only scanty rains. The weather on the coastal strip, Gunob, and in the mountains along the coast, is influenced by monsoon winds. Gunob, including the Red Sea hills, has its rainy season in November - December. Only a small area between Aulib and Gunob, in the hills and on their western slopes, may experience two rainy seasons. The degree of rainfall regulates the amount of durra sorghum that can be grown and influences the conception of camels, whose calves are born during the rainy season that follows one year later.

The Amar'ar once used to be wealthy in camels. Struck by very serious drought forty years ago they have since lived precariously close to total impoverishment, and have been forced into dock labour in Port Sudan.

The camel in local life

The Amar'ar use their camels to produce subsistence food, as a form of wealth which can be transported. Camel milk and durra form the basis of a household's diet. The camel, compared to dryland cattle or fields, has a distinct advantage in that it provides food throughout the year. The quantity of milk depends on the breed, the quality of the pasture and the age and stage in the reproductive cycle. The yield is generally higher than that from cattle under comparable conditions. Beja also utilize meat, skins and fat from the camels when made available through the slaughter of excess male calves or fairly old females. An immediate need for meat is usually met by the slaughter of a sheep or a goat. Camel meat is not a preferred food, but when it becomes available it is readily eaten. Limited parts of the carcass may be stored in the form of fat and dried strips of meat. The camel skin is less important for household use, except as raw material for sandals and whips, but is usually sold. Wool is disregarded.

The Amar'ar differentiate between three categories
of camels, shallagēa, arirīt, and matīāt. The shallagēa are the sturdiest and are the best milk producers. The arirīt are also fair milk producers but their main advantage is their endurance as transport animals: they can cover long distances at a steady pace without water. The matīāt are the most slender of the Amar'ar camels and by far the fastest, although they tire quickly. They give comparatively little milk but are easier to manage than camels of the other categories.

The basis for the development of three different types of Amar'ar camels lies more in the adaptation of the young camels to specific pastures with a concomitant differentiation of nutritional status than in selective breeding. Inter-breeding occurs frequently. If anything, there may be a difference in physical appearance between matīāt and the other types. On the other hand, both arirīt and matīāt camel calves are said to develop into shallagēa if they are brought to the coast and reared there from an early age. Three other local categories of camels, perhaps nearer to breed status, should be mentioned. Those of the Bisharīn Beja (to the north) are better riding and transport animals than any of the Amar'ar types. The Rashaida arabs (to the south-east) have two different breeds, one which is a better milk producer than any of the others, and one, the Anafi, which is a renowned trotter. The economy of these two tribal groups is more clearly commercial than that of the Amar'ar (cf. Dyson-Hudson, 1972).

The Amar'ar camel, of whatever type, is a multi-purpose animal. An owner herding about a hundred female camels needs no more than one sire which is selected on a basis of size, conformation and his dam's milk record. A strong body and a slender "waist" are believed to indicate speed. The importance of hardiness, milk production and mobility accounts for the limited interest shown by the Amar'ar in cross-breeding with, for example, the Rashaida camel, which is very productive but whose milk is said to be less palatable, and which above all is not a swift mover.
Occasionally, the owner of a female camel chooses a sire on the basis of his running capacity. Thus he may contact the owner of a Kiliwau camel, a breed originating from the Bisharín. Sometimes human assistance may be needed for copulation to be achieved, but generally the camels are left to manage mating by themselves. The male camel may be removed from the herd when the owner does not consider the season suitable from the point of view of the health of the animals, or considering their lactation which is said to come to an end on the twelfth day after a successful mating.

A majority of male camels are either slaughtered as young calves for immediate consumption or are sold. Of the remainder, which are not castrated, some are maintained for pack and riding purposes and as sires. The loading capacity varies considerably between different breeds and types of camels. A standard load, however, is claimed to be two sacks of durra and a driver, making a total of about 250 kg for a walking baggage camel. A trotter carries less weight. The speed when trotting is approximately 12 km per hour. A five-hour trek is then possible for some five consecutive days. Then the animal needs a two-weeks rest. In principle, camels should have a six-hour daily rest since they are ruminants (cf. Acland, 1932), but on long-distance travel this rule cannot be obeyed.

Skill in camel riding is a highly valued masculine virtue in Beja culture, in contrast with Cushitic herdsmen further south in the Horn of Africa who do not ride their animals. The dexterity of the Beja rider and the high prestige value of the skill is demonstrated in camel racing. An Amar'ar rider should be able to meet the proverbial test of riding standing upright with a bowl full of milk without spilling a drop while riding at a high speed. He should also be able to ride with a live camel fly held between his knee and the camel, without either killing the insect or allowing it to escape.

Although Beja's role in long-distance trade has
dwindled with the advance of transport technology, the camel still has an important part to fill in shorter range travel. Beja are dependent upon supplies of durra sorghum and finger millet for the diets of both animals and human beings. These grains are sometimes grown in the river canyons, but the Beja often have to trade for them, and pack camels are used to transport the purchases. Camels are also important in carrying tents and household equipment when the household is on the move.

The life of a mish'arib is an adventurous one, but also full of hard work. This picture is from the big wells on Khor Ariab

Camel rearing is highly significant in the ethos of the Amar'ar society, and camel herding has a strong emotional appeal. Mish'arīb, those who tend the camels, are often young unmarried men who live a wild, independent, adventurous life. Their fathers, by their proprietorial control of camel herds, tend to exercise a strict authority over their sons long after these have grown up.

To the Amar'ar camel life has a romantic glamour; the men are said to become strong, virile and attractive
to women from their diet which consists primarily of camel's milk. It is the right and duty of the oldest son to become a mish'arib. When family labour is not available, a mish'arib can be hired at the cost of one young male camel per annum (or the equivalent in sheep). Alternatively, the entire household may follow the family camel herd if other activities such as farming or small-stock rearing do not demand their attention. But camel tending is usually the responsibility of men. Women, by tradition, have a certain limited role to fulfil in the care of small stock whose needs they tend to in the morning before grazing begins when they check the state of health of the animals. Occasionally, if no boys are available the women may herd the small stock, but they do not milk sheep or goats and they take no part in the care of camels. Their domain is the home.

The nomadic home is the base of livestock herding. Only a few milch camels are kept in the vicinity of the settlement to cater for the daily needs of household members. If pasture is scarce the camels may be kept far away, distances being governed by the watering needs of the different species. Donkeys are used to carry household water, but one or two baggage camels are usually kept near to the camp to assist with transport requirements. All Amar'ar recognize i'dāmar, the permanent home place where women, small children and old men dwell permanently when climatic conditions permit. It is the young and strong men who move with the camels.

Camel ownership is a male prerogative. As with many African pastoralists, an Amar'ar man obtains stock from his parents by two processes. The first concerns significant ante-mortem gifts, and the second inheritance according to Muslim law. The former benefits mainly or exclusively sons, and by the second (which probably is quantitatively less important) sons get a double share compared to their sisters. Although women may nowadays get some formal title to stock, as far as the Muslim law is followed and not Beja indigenous traditions, they rarely get the practical authority over them but have to cede
this to a male relative. Young men are urged into early marriage by their fathers who will contribute to the new conjugal herd in terms of small stock but retain authority over the sons and over the camels that they have named for the sons. In this way the fathers maintain their authority until they die or retreat into senility. After the father's death all brothers ideally get a share in all kinds of stock but if there are very few camels the older brother will act as a trustee for his younger brother's animals.

Dwindling wealth

Since the three-year drought in the early 1940s, many Amar'ar have been forced out of their traditional niche. To them, camels are no longer the dominant base for their economy. (Plate 2) The relative importance of small stock is likely to have increased and many Amar'ar households have been forced to take up paid employment in Port Sudan. This may be the sole major source of livelihood or a supplementary venture into which a younger son can engage. In 1971 tribal wealth was considered to have dwindled so much that the Sudanese Government proclaimed a general exemption from taxation. Among those remaining in the pastoral sphere there are herd-owners who are quite wealthy if one counts the value of their capital, some having up to 150 camels. A balanced family herd, containing ten or more females of varying ages can provide a relatively secure economic position with enough milk produced to cater for its herdersmen and other household members if these both live close to the herd and have good access to markets.

The minimum market value of a family herd is 2 500 - 4 000 Sudanese pounds (LSD). It would be difficult for many ex-pastoralists to rebuild family herds solely by the purchase of new animals. The social organization does not provide enough economic insurance or sufficiently efficient principles for redistribution to cater for those who lose a major part of their herd. To rebuild a herd solely through biological reproduction is a slow process which calls for skilful management as well as a sub-
stantial input of manpower which may be difficult for people living from hand to mouth (Dahl, 1979). With high mortality and low fecundity rates, the growth of the area herd is limited. For a majority of Amar'ar camel herders, the herd is at best a constant resource containing little promise of capital growth. A small herd, which if sold represents a substantial amount of money, may if utilized for subsistence merely produce enough for making a living. Spencer (1973) has commented on the slow growth of camel herds of the Rendille in northern Kenya.

Old Amar'ar men claim that before the 1940s each female used to give 10-11 calves during her lifetime. Nowadays, however, many females are not allowed to bear more than 7-8 calves after which both strength and fertility seem to decline. A restrictive strategy has its base in the small number of female camels available, which forbids the risk-taking that short interspacing would involve. In particular, camels are not mated when droughts are anticipated. The age of first calving is five years or older. Old females are nowadays slaughtered at around the age of 21-23 years; formerly they were maintained until the age of 27-29 years.

Camel reproduction is slow and risky. Many Amar'ar have not succeeded in replenishing their herds after recurrent droughts
The camel population

The general trend of camel population development is a drastic decline. It is difficult, however, to find a sound basis for safe quantitative statements on this decline or more specifically related characteristics of the "area herd" of the Amar'ar, i.e. all the camels to be found in the territory. The difficulties are representative for the scarce data that camel research has to be satisfied with. A few rough censuses have been made in annual provincial reports using simple extrapolating methods from "guestimates" without compensating in the projections for climatic fluctuations and associated variations in mortality. The least unreliable census of livestock in the Red Sea area seems to be an aerial count carried out in December 1975 (Sudan Veterinary Research Administration, 1977). This report identifies a few vegetation zones on which stock countings are based. However, the report neither provides any information on age structures in the area herd, nor does it introduce data sufficiently detailed to make it worthwhile to try to separate the Amar'ar area from the entire Red Sea Province. The total number of camels in the Red Sea Province was around 100,000 according to the census. About half of this number was found on the coast or in the mountain area (ibid). Such a concentration is, of course, logical given the fact that the winter rains were due on the coast at the time of the survey. This fact is reflected in a high relative density of animals, 1.85/km². The vast inland held about 20 percent of the area camel herd scattered to show a density of about one-tenth of that of the coast. The animals kept in Aulib at the time of the survey were most likely held waiting for the summer rains as an alternative to trekking to the coast. High concentrations of camels were also observed in the Gash and Tokar (Baraka) deltas where another 20 percent of the area herd was found (Map 1).

If macro-data are difficult to get, micro-level herd "demography" puts us on no firmer ground. The above-mentioned report provides "mean group sizes" referring to the clusters of camels that could be identified from
the air. Unfortunately, there seemed to be median figures in the report. One might expect these to be even lower than the averages since the distribution is probably not normal but logarithmically normal. A second reflexion on the survey is that while animals in a family herd are kept together for herding purposes, one may wonder if the groups distinguished from the aeroplane really were complete family herds, or if they were parts of larger ones, scattered due to sparse pastures or for other reasons. With the sole exception of the Tokar delta, which held camel herds averaging 12.5 animals, the average herd size varied between 3 and 5.5 head. The value of this figure as an indication of size of household property is debatable. Firstly, camels do not keep together when browsing (Dahl and Hjort, 1976) and even if it is possible to identify a family herd, any herd may contain animals trusted to the herdsmen as well as property in the more narrow sense.

There are considerable obstacles to obtaining information on the sizes or age structures of family herds. Any interest from outsiders in numbers or ages of this sort raises suspicions. Every herdowner tries to keep secret his real wealth, having several good reasons for this. The Muslim charity to the pious and poor is regulated according to individual wealth; the exemption of Amar'ar from secular taxes is an insecure asset that may be changed at any moment. Furthermore, the very right to individual animals is often an issue which could be debated. People who need to leave pastoralism temporarily for other ways of making a living may leave their remaining animals in the care of others. Time goes by, the migrant never returns but his camels and their offspring remain. The herdsmen gradually start to regard these animals as his own property, hoping that the former owner or his heirs have forgotten the whole issue. The more time passes and the less talk there is about the background of these animals, the stronger will his claims to these animals be. Hence, there is a common understanding that the origins of individual camels should never be discussed, except on the occasion of negotiating an inheritance among heirs.
Three patterns of camel pastoralism

1. **Arir ët camel pastoralism in Aulib**

The vast plateau area to the west of the Red Sea Hills is only sparsely covered with vegetation. Common trees on which camels browse are sanganëb (*Acacia tortilis*) and kitr (*Acacia mellifera*). Among the shrubs attractive to camels one finds singidd (*Indigofera spinosa*) and gafarëb (*Salsola baryosma*). Grasses also provide the Aulib camels with fodder, notably the tall perennial shûsh (*Panicum turgidum*), which is used for fodder also when it is dried. Only if the rains fail completely for two consecutive years does it become grey and useless. Many annual grasses are excellent for camels but disappear comparatively quickly after the rains. Grasses like shûsh are easy for the camels to graze, while they have difficulties with short grass.

Aulib is suitable for camel and small stock rearing but not for cattle. Animals and people need to be dispersed over large areas. One seldom finds clusters of houses. Normally, each family lives by itself, but within walking distance (3-5 km) from a neighbour. This pattern was documented in the aerial survey (Sudan Veterinary Research Administration, 1977). It suggests in average 0.18 nomadic houses per km². The same report suggests a human population in Aulib of around 42 000, about equally divided between nomadic and sedentary settlements.

In Aulib one can distinguish between two herding strategies. The first is to remain on the plateau preferably fairly close to i'dämär, migrating some 5-6 km daily or weekly in different directions. The second strategy is to carry out a few long-distance treks. This is often done in groups where relatives help each other with the daily shorter movements for pasture at stopping points. Thus neighbours (kinsmen) cooperate and enjoy each others' company, agreeing daily on where to make the afternoon stop of the next day.

The hardy arir ët camels are found in Aulib. After
a successful rainy season (July-September) when the autumn pastures are fresh and good, the arirît can go 5-8 days without watering. Under very dry conditions they can be without water only for 2-3 days. On hot days one camel drinks 60-80 litres. A very large animal may take up to 100 litres. In the winter (November - January) when the weather is cool and dry, the arirît are usually watered every 5-8 days, but are in fact capable of going up to one month without watering if necessary. This is the best period of the year, when the animals give much milk. If proper pasture can be found, herdsmen claim that this period can be extended up to six months. Well-kept arirît give 2.5 - 5 kg milk at the midday and evening milking, and 3.5 - 5 kg in the morning. The volume of milk production depends heavily on the quality of pastures. Due to the seasonality of camel mating and the quality of pasture, access to milk may become difficult just before the rains, particularly when normal reproduction has been upset by a long drought, so that the competition between calves and people for milk becomes acute.

A healthy camel gives up to 5 kg of milk at the midday milking
Availability to pasture rather than access to water decides the migration patterns for the Aulib camel herds. They move irregularly across Aulib in search of the little fodder available. If it rains in a locality for some three consecutive days, there will be a scramble for the anticipated kurai (pasture). Years with good rains see a gravitation of livestock toward the western slopes of the Red Sea hills, where the potential for high quality grazing is best. During such years Aulib herds even penetrate down towards the Gunob strip without too much of an effort, and get a well-needed salt treat. The 'adlib bush (Suaeda fruticosa Forsk.), growing along the coast, offers salty pasture all the year around. Other plants, relying on rainfall, are not as salty and supplement the Suaeda fruticosa browsing during the rainy season.

A slightly modified seasonal migration pattern exists north of the Red Sea hills. Here, on the Atbai, camels are in a better position to browse their way to the coastal strip. Hence a pattern of transhumance emerges. The Atbai herdsmen are annually able to spend a couple of months browsing on Suaeda fruticosa at the coast, as a salt treat for their camels. Some northern Amar'ar people regularly inhabit the Atbai plains which are otherwise dominated by the Bishari.

Many Beja claim that selling camels is anomalous. Nevertheless, there are many who do so in order to meet monetary expenditures, which include the purchase of food items and consumer goods, payment of bridewealth and other transactions which may be made in cash as well as in livestock. In Musmar the price of a good riding camel is at least 500 Lsd. A top quality milking female will cost 400 Lsd: an immature female up to 200 Lsd and a female calf between 1.5 and two years of age at least 100 Lsd. Prices in the Port Sudan area are higher.

Many animals are taken away from the area to larger markets inside Sudan, in Egypt or in Saudi Arabia (Map 1). The
Sudanese markets are in Atbara and Ed Damer, from whence the camels are brought to Omdurman. Most of the demand in these markets is for good loading animals. Saudi Arabia buys riding animals and transporters, while the Egyptian market takes slaughter animals, female breeders and transporters. Beja traders drive herds of 50 - 150 animals in a 15 days day-and-night trek through the Nubian desert, preferably during the winter time, when the demand in Egypt is at its highest and the journey is least arduous. The camels are then sold at Daraw, Aswan, Esna or even in Cairo. Such traders should be formally licensed but a good deal of smuggling and black marketing of currencies takes place at the boundary. The Rashaaida Arabs are also heavily involved in camel exporting and handle much of the Saudi Arabian trade.

According to local opinion, the Beja trade in export camels has declined. There are small price differences between Egypt and Sudan compared to fifteen years ago. There is also severe competition from camel traders coming from the west of Sudan and using the traditional "forty days route" to Egypt.

2. Matiāt camel pastoralism in the khors

The khors and the mountain areas surrounding them present a special case of camel pastoralism. Here we find matiāt or ṭi'hibqualda camels which feed almost solely on the hib tree (Salvadora persica). (The Arab word for ḥib, used frequently in conversation, is "arāk".) These camels are so adapted to this rather unusual diet that they prefer this pasture for most of the year; only during the rainy months do they change diet. The matiāt dominate the khors because other camels do not eat Salvadora persica except in emergency. Both the arirīt and shalāgēa can be fed Salvadora persica in critical times, but they react initially with diarrhea and refuse it until hunger forces them to eat it. The matiāt live in the khors for most of the year. They do not migrate such vast distances as do the arirīt. During the extremely hot and dry days they move up into the mountains
to find water ponds, *Salvadora persica* trees and cool air. No herdsmen follow them during such days.

The major areas for *matiāt* are all in the Sinkat-Gebeit-Erba-Kamob Sanha area, as well as the remainder of Khor Amor, all of Khor Asot and the upper part of Khor Arba'at (Map 2). *Salvadora persica* is also found in some small khors on the eastern side of the Red Sea Hills.

The *matiāt* become very thirsty from browsing on *Salvadora persica* and require daily watering for most of the year. One animal consumes typically 30 litres per watering during cold days and at least double the amount twice a day during the hot months. They give considerably less milk than *arirīt* camels, typically only 1 - 2 kg at the midday milking.

If *matiāt* were to feed all year around on *Salvadora persica* they would develop chronic diarrhea and eventually die. During the rainy season most *matiāt* are therefore herded outside the *Salvadora persica* khors to feed on fresh grass pastures. *Matiāt* reproduction, like that of *arirīt*, is geared to the rains and mating as well as births occur in the July - September period. They are often taken to the Khor Arab area during these months.

Unlike other camels, *matiāt* are hardly ever sold on the market. It is difficult to move them the distances to the markets, and so there is little export demand for them. They are maintained in small numbers, usually between three and five animals per household. These households keep *matiāt* as a supplement to farming or small stock rearing. This shift in emphasis reflects a shift in priorities of risk-taking with employed herdsmen. During the rainy season a number of households cooperate in employing a man to take the animals to the pasture. Since this is a busy time for farming the *matiāt* owners are themselves too occupied with their farms to be able to move with the animals.
A herd of young females being brought back to the Red Sea Hills from their Gunob pastures

Many people in Khor Amor keep small stock flocks, mainly of goats, of 10 - 20 head per household. They are kept primarily to provide meat and milk for the household and are sold only occasionally. The goats feed on shush and give 1 - 1.5 kg of good milk at morning and evening milking. Goats' hair also plays an important part in the household economy, providing material for the production of mats for bedding and the inner walls of the nomadic hut. The sheep are difficult to manage since they do not browse like goats and do not feed well on Panicum turgidum. They give less than 1 kg of milk per day.

3. Shallagea camel pastoralism on the coast
The shallagea (coast) camels are adapted to the feed available on the coastal strip. They browse on the salty Suaeda fruticosa (both the 'adlib variety and the similar but smaller hadmal), supplemented with the leaves and fruits of mangrove (sha'warab), which are also an emergency food for human beings. During the Mahdīa when the region suffered from severe starvation, the survival of the coastal people was due to the fruits. The shallagea are very skilful at walking into the sea and nipping
Map 2: Northeastern Sudan

- National boundary
- Road
- River
- Amar'ar
- Tribal group
- Amar'ar territory
Map 3: Amar’ar territory in outline

Railway
FADLAB
Family group
Khor or Wad
the lemon-like fruits from the mangrove stands. They learn where it is possible to walk on the sea bottom well enough to do it during the day and also at night. Frequently they wade so deeply that only the head and hump are visible above water. Mangrove trees are found along the entire Red Sea coast of Sudan. *Suaeda fruticosa* concentrations are found especially in the Baraka delta and its contributory khors. Although salty, this plant does not grow on especially salty soil; the occurrence of *Suaeda fruticosa* bush is considered as a sign that durra farming is possible. This fact has caused great tension between those Amar'ar who primarily herd shallagea and those who have lost the bulk of their family herds and try dryland farming during the sometimes rainy months of November, December and January. When the *Suaeda fruticosa* bush is cut, the quality of the grazing deteriorates very quickly, and simultaneously ecological imbalance occurs through severe wind erosion. The durra harvest from these rainfed farms on coast is small and unreliable.

The human population of the coast outside the towns reckoned from the December 1975 aerial survey was about 45,000. The density of the permanent and nomadic housing was much higher here than in Aulib, around one house per km².

The shallagea are larger than the arirît and the matiât. They are herded on the coast at least six months of the year (December - May). If there is rain in Aulib, most shallagea will be taken to the western side of the hills for some months, and if it rains on Atbai to the north the pasture there will be utilized as well. The shallagea herdsmen claim that their camels can feed well even on *Salvadora persica* and that the health status of their camels is so good that they never overeat on any fodder (in contrast to both matiât and arirît). The reason given by mish'arib for the good health of the shallagea is their *Suaeda fruticosa* diet. The urine of the shallagea is a traditional medicine and people come from as far away as Somalia to obtain it.
When on the coast the \textit{shallagea} require watering daily or possibly every other day. This is due to the salty browsing, which also causes them to urinate greatly. They drink 80 to 100 litres at each watering. In the Baraka delta where the \textit{shallagea} rely solely on \textit{Suaeda fruticosa} the animals drink by night and browse during daytime. Their herdsmen build large mud containers next to the water holes for this purpose. The containers are called \textit{o'ser} in Tubedawiye and "girba" in Arabic. They are found among all Sudan camel herders.

Apart from watering, the tasks of the mish'arib on the coast are reduced to morning and evening chores and midday milking. During the day the camels are allowed to wander, a few leader camels having their forelegs tied together. This makes the entire herd less mobile and easy to locate.

The \textit{shallagea} herds are the only ones that the Amar'ar systematically divide into dry and milking herds. Very few males are kept. One of our informants maintained only one bull to 150 females. By night, or when the herd is stationary for any particular reason, only the males are tied; this is enough to ensure that the females will not stray.

The \textit{shallagea} are very good milkers, especially during the three one-month periods, roughly November, March and July, when \textit{Suaeda fruticosa} is in fruit. At the early night milking one camel may give up to 6 kg. Three hours later it may give another 3.5 kg. The morning milk could then amount to between six and seven kg. These figures, provided by the \textit{shallagea mish'arib} represent an average good but not exceptional milk production for human consumption. The animals may be milked more frequently, and herdsmen claim that good camels give 3.5 kg each milking if milked at two-hour intervals during the day. With the three milkings per day, which is a common practice, each animal gives a daily yield of 15 - 18 kg. During good rains and with excellent
pasture on the Aulib side, each of the three milkings may provide some 6 or 7 kg. One wealthy camel trader was of the opinion that he had achieved the maximum milk production possible from shallagea. His few females were feeding on good quality cattle fodder purchased in Port Sudan and were yielding 22 kg per day at three milkings. He claimed that higher production could only be obtained from Rashaida camels.

Given such high yields and sustained production, two milking females can provide for a coastal family of man, wife and six children living near Port Sudan; the milk of one shallagea being kept for subsistence and that from the other being sold at 0.25 LSD per rattel of milk (one rattel is approximately half a kg). The money is mainly used to buy durra.

The shallagea have a different breeding season from the matiät and aririt; they breed on the coast during the monsoon winter rains in November - December when the weather is cool and good pastures are available. If a mish'arib considers the condition of his animals too poor for breeding he simply keeps his males away from the family herd. However, this is only an extra preventive measure since males are not normally interested in covering females when they are starving.

Those who specialize in providing the town market with milk products frequently themselves live in Port Sudan and employ salaried herdsmen, sometimes on a cooperative basis, as one herdsman can manage 60 to 70 head. When browsing becomes scarce the town shallagea are given about 2 kg of durra in the evening in order to maintain the supply. Town camels receive many kinds of waste materials, including mushuk, the date residue from wine production. There are mixed feelings about the appropriateness of keeping camels in town. To keep riding camels, however, can never be inappropriate, and many of the Amar'ar tolerate the trouble and expense of having an animal tied outside the dwelling in order to satisfy leisure needs rather than solving transportation problems.
Change and constraints

The three different patterns of camel rearing among the Amar'ar represent different ecological niches as well as differences in the importance ascribed to the camel. Shallagāa and arīrīt are milk producers and trade goods for pastoralists who depend directly on their livestock for a substantial part of their diet, while at the same time supplying the commercial camel markets. The role of matiāt is more subordinated to farm production. The matiāt provide milk and meat for human consumption but without any substantial labour investment.

It must be repeated that there are considerable numbers of the Amar'ar who have no camels and whose livelihood depends upon small stock shepherding, farming and urban occupations. When the great drought took place in the 1940s the British had for long endeavoured with little success to recruit labour, for example, to the cotton schemes at Tokar and Gash but found the Beja very unwilling to take up salaried work. After that crisis, however, the Amar'ar never really recovered. Widespread poverty and the opportunities for wage income in Port Sudan and Atbara altered the logic of labour allocation for drought-stricken nomads. More recently, an increased demand for labour in Saudi Arabia has lured young men away from camel herding.

A majority of the Amar'ar are now wage-earners in Port Sudan. They represent varying degrees of commitment to the pastoral sphere. Some are members of Aulib households who stay in town only for a limited period. Most common are those who work in port for a few weeks in order to earn enough to buy two sacks of durra and bring them home. Some, however, remain long enough to appear semi-permanently settled in town, even if they intend to return as soon as the family wealth allows them to do so. These may be men who have their family in Aulib and who send remittances regularly. Among those permanently living in town are some who have severed all links with pastoralism, and also those who have
some security wealth in the form of camels, inherited or acquired by other means, or who invest their savings in animal wealth. Such livestock are kept in Aulib in the owners' absence by one of his relatives (normally a brother) or by an employee. If they are daring, such urban stockowners may attempt some trade in small stock. One category of townspeople thus has as its main goal to regain viability to their household units in Aulib; for the other the Aulib livestock is a subsidiary activity supporting a mainly urban-focussed economy.

The development of an urban market for meat and milk and the job opportunities offered in Port Sudan have become essential to Amar'ar pastoralism and maybe even for the very existence of the Amar'ar as a local group. Without the port, large parts of the community would have been scattered over various settlement schemes elsewhere in Sudan. As things stand, Port Sudan offers drought-stricken households a living either by direct involvement in wage earnings or trade, or indirectly through the exploitation of kinship links to those who have secure incomes. An opportunity is provided to live and work in the area for long enough to attempt to rebuild the family herds.

The markets in Port Sudan and other towns offer important income to the herd owner
The factors which from one point of view seem to reinforce the viability of the pastoral undertaking, also threaten it. For people balanced on the margin of viability there is a clear risk that the temptation of good prices or emergency sales to meet short-term needs will cause excessive selling, particularly of female stock, beyond the point at which herds will be able to reproduce properly. Also, wage opportunities distract manpower from camel rearing. Immediate needs may force too large a number of able-bodied persons to abandon herd management. The decrease of herding manpower tends to encourage the concentration of herds in the hands of the wealthy. In the end this may create a shift toward increased specialization both on the coast and in the interior, a more extensive form of pastoralism producing animals for the livestock market.

Among the Amar'ar there is a general belief that living conditions in the area have worsened within living memory and that this is related to environmental changes. Viewed over a longer time-span there is little to indicate that the vegetation cover has ever been substantially better. However, when both herds and land are considered, the entire Amar'ar region has deteriorated in production capacity due to severe drought periods upsetting normal herd reproduction, which again has negative implications for a family's capacity to withstand drought. There are also some recent signs of desertification, experienced not as a general deterioration but by increased quantities of sand in the khors.

Some changes brought about by colonialism must also be mentioned. It must be recognized that there have been no significant development projects in the region which might drastically influence the role of rearing camels. Whatever changes have been experienced in the conditions of camel rearing have been unplanned in the sense that they have not deliberately been related to changing the camel economy or were the side effects of commercial colonisation more related to agricultural production than to animal industry. Secondly, the colonial peace made
intertribal boundaries much more rigid and drought adjustment through migration more difficult.

It is obvious that economic change is furthered by environmental stress. The change in land use implied by an altered consumption pattern divorced from the traditional pastoral land use not only puts pressure on land for cultivation but leads to increased wear on forestry resources. Regardless of whether grain is bought or locally produced, its preparation into food invariably requires much more fuel that is consumed by camels when milk is a staple.

The problem of competing land uses is particularly acute at the coast, and close to Port Sudan. This is also where those who are still active as pastoralists feel threatened by farmers. The cultivators are generally themselves former camel people of the same tribal unit practising dryland farming from a lack of any alternative. Their only resource is a traditional claim on collective land, which they can transform into rights to carry out occasional farming with the negative effect that the browsing that is a base for the corporateness is destroyed. As in so many border areas between farming and pastoral areas, farming is primarily a symptom of poverty.

Arirît herders in the interior have not yet experienced competition from cultivation and perhaps are unlikely to do so. The matiât in the khors graze close to cultivated fields but rely substantially on the *Salvadora*, the supply of which does not appear threatened by khor cultivation. There are, however, other threats to an operative camel-rearing system which stem rather from the labour demands associated with a mobile adaptation and the deleterious side effects of labour migration. The *arirît* rearing pattern is particularly vulnerable to manpower shortages since it depends so much on a high degree of mobility. Experience in other pastoral communities (cf. Dahl, 1979) shows that manpower shortages linked with labour migration tend to make the
population of people and animals more stationary, which may create a situation of local overgrazing. Part of the adjustment may be a gradual transition to a commercially oriented, more stationary form of small-stock pastoralism.

Camel rearing systems are delicate combinations of labour, land resources and expensive animal capital. The camel-based economy of the Amar'ar is already hard pressed under the competition for land, labour and breeding stock. It is difficult to see how, in the future, these pressures could be eased, for example with a continued large-scale inflow of refugees from Ethiopia and Eritrea, the establishment of an American naval base at Suakin and the potentiality of large-scale mining in the Red Sea hills.

REFERENCES


THE DROMEDARY OF THE HORN OF AFRICA

Brian J. Hartley

Summary

There are an estimated four million camels in the Horn of Africa. The camel is the most adaptable of animals on the arid rangelands, and the least damaging to the ecosystem.

The nomadic stockowners rely on the camel for their subsistence and for the mobility essential for their survival.

A lucrative trade in slaughter animals for export supplements a strong local demand.

In spite of its great importance, the camel has generally been neglected by governments and development agencies. There should be a new and better appreciation of the camel's value.

The land, the people and their livestock

That part of N.E. Africa which lies East of 40° long., and between the Equator and 15° North lat., may be said to represent the Horn of Africa at its largest. It contains some 500 000 sq.km of arid and semi-arid rangeland. The Horn is not one defined territorial jurisdiction; four different countries rule the area - from North to South these are Ethiopia, Djibuti, Somalia and Kenya.

The climate is variable, with extremes of heat in low-lying areas, and cool temperate conditions over high ground. Rainfall is mainly dependent on the N.E. and S.E. monsoons; the regularity and quantity is influenced by altitude, with variations from 500 mm in the most favoured areas, down to 80 mm, or less, in coastal areas
to the North. In spite of a generally low and erratic rainfall, its bi-modal pattern favours plant and animal growth.

The dominant plant communities are found in the savannas, shrublands and grasslands. Range type and productivity is much influenced by increased water availability as found in riverine areas, areas of impeded drainage, and in enclosed basins. There are evergreens and forest relicts on high ground. The halophytic vegetation of the sea shores, and on the salt flats and gypseous areas, provides a striking contrast.

Water supplies vary, from abundance in riverine areas to the other extremes of aridity. Here permanent supplies, whether underground or surface, are non-existent and reliance must be placed on seasonal surface supplies and on harvested and stored water from a rainfall which is often deficient and erratic.

The people of the Horn are mainly pastoral Somalis and Afar (Danakil). On the Western borders Oromo (Galla) pastoralists and mixed farmers occupy the land. Islam is the main religion. A few pagan communities are found in the West. The total population may be five million.

The area is outstanding as healthy livestock producing country, and camels, cattle, sheep, goats and equines are kept. The importance of the different classes varies according to range conditions, water supply, and stock-owner preference. Almost all of N.E. Africa's camel population is to be found in the area described. Exceptions are those camel herds found to the West, on the arid plains bordering Lake Turkana (Lake Rudolph); here the camels are owned by the Turkana and others, such as the Gabra, who move in at times from their main grazing country to the East to seek water in the lake.

The Gabra are a wide-ranging, camel-owning tribe who occupy the rangelands of the cattle-owning Boran of
Southern Ethiopia and supply burden camels for that tribe. They also move southwest into much drier country, to the Rift valley and the basin of Lake Turkana. West of the lake are the Rendille whose way of life and culture is, like that of the Gabra, closely bound up with camel husbandry. These two tribes take blood to drink from their camels. They also use them as burden animals.

South of the Rendille and southwest of Lake Turkana are found the Turkana, a major camel-owning tribe of the area, and the Samburu and the Pokot which are tribes with comparatively small numbers of camels as they have only recently (perhaps in the last 80 years) taken to camel husbandry.

West of the lake are found the main camel herds of the parainilotic Turkana. Their rangelands are intensely hot and arid but the good camel browse and salt-water springs and wells make this ideal country for camels. The Turkana own cattle and the transhumantic movement of their herds to the western edge of the Rift valley and over into Karimoja is followed by some camel herds. Peaceful association and intermarriage with one of the Karimoja tribes, the Mathiniko, has enabled this tribe to acquire camels.

Turkana, Samburu, Pokot and Karimoja take blood from their camels but do not use them for transport as baggage or riding camels.

Among all the tribes mentioned the camel is the most highly prized animal, its value being reckoned at four times the exchange value for other classes of livestock. (One female camel = 4 cows or 40 sheep and goats.

Range management and livestock production

The traditional and most acceptable system of range management in the Horn uses the range on a rotational basis,
with stock moving from dry season ranges with permanent waters on to wet season ranges, where reliance is placed on temporary seasonal waters and on the green forage, which can support camels, sheep and goats with only an occasional drink. With the return of the dry season the livestock move back to the dry season ranges and the permanent waters.

There are two main rain seasons. The March – April rains are the heaviest, and are followed by a short, hot spell. The second rains follow in September – October, and this is followed by the main dry season, which is the cool weather.

In the North West an additional rainfall occurs in July – August, and the September – October rain is less. On the Northern coasts a "winter" rainfall may occur in favourable seasons.

In spite of the seasonal trends, moves are opportunistic to take advantage of range conditions, because the rain tends to be erratic and may fall heavily on some areas and leave others dry. Other moves may be transhumant in character, such as the annual "winter" movement of livestock from highland areas down to coastal areas, which are too uninhabitable for comfort during the hot weather. In other regions there may be positive movements in and out of areas which become seasonally flooded.

During the rainy season all stock are spread out over the range, with the camels going the farthest and making the most frequent moves. As the dry season approaches, the livestock are separated according to the class of animal and pasture and water requirements - with cattle watering every 2 to 3 days, sheep and goats every 3 to 8 days, and camels every 10 to 20 days. Cattle and camels are traditionally divided into dry herds and milking herds by the principal breeders, and then the dry herds range farthest, with the camels 100 km, or more, from water. This is the traditional system, and
the ideal. However, in recent times conditions have deteriorated. Water supplies have been developed without any consideration of range values. Sedentary occupation around permanent waters continues unchecked, while the spread of cultivation has transferred communal grazing lands to cultivators, who have acquired individual rights of tenure.

These changes have brought about an increase in the cattle, sheep and goat numbers - but camels remain a basic resource and necessity, and in the drier country they are of vital importance. When drought comes as it frequently does, the camel emerges as the essential provider for subsistence and for mobility and, with it, the means for survival. As the Somalis say -

"A camel man is a man,
A goat man is half a man,
And a cattle man is no man at all."

The camels of the horn

Foreigners have attempted to classify the one-humped camel of the Horn into breeds, and have given them names associated with the region in which they are raised and generally kept. Among the camel breeders they are known by the name of the people breeding them. They are called the camels of such and such a clan. For example, "Gaala Kiuk Hankeeba" - the camels of the Kiuk Hankeeba clan (of the Assahimera division of the Afar). However, the 'breed type' does reflect the sort of country on which the camels are bred and, in the case of animals for saddle use, they should be capable of a fast and easy gait.

There are small numbers of riding camels among the Afar from the Djibuti border northwards along the coast. There are mountain camels in Northern Somalia, and steppe camels, and those of the desert shrublands; and there
are the large camels of the dense shrublands and flood plains of the inter-river area of Somalia.

As an example of difference in size, the camels of the Iise Somali breeders of the North are small, compact animals, adaptable to the plains and steppes and to the stark volcanic mountains, and the great heat of those regions. In contrast, the camels of the Hawiye clans in Southern Somalia are massive beasts, on average perhaps one-third heavier than the Northern type.

Ownership patterns

In the Horn most camels are owned by those of the Muslim religion. Pagan groups of Oromo (Galla) and Gabra, and others, also own camels, and they drink blood from camels. The Christians of the Highlands of Ethiopia do not own camels, and they do not drink camel milk, nor eat camel meat.

Ownership traditionally starts with the ceremony of "Navel Cord Tying" (Huddunhid Somali, Ikyoto Afar), when at birth a male child is presented with a she-camel calf, born about the same time. The navel cord is sewn into a small skin pouch, which is then tied round the neck of the gift camel calf. As the boy grows he may receive more camels as gifts from his father, and from his brothers and relations - and so his herd increases. When he marries, he will receive more camels and other livestock, for then he must provide his wife with a subsistence flock of sheep and goats. Among the pastoral Somalis this should be about 100 head of mixed sheep and goats. He should also provide two burden camels for water and ration transport and for moving the nomadic camp. He may also supply one or two milk camels to supplement the sheep and goat milk, and to allow the wife to make this into subag (ghee, or clarified butter) to be eaten or sold in the market.

Although recognized as the owner of certain camels, the beasts will collectively be known as the camels of
such and such a clan, and will bear the brand (sumad) of this clan. "Over his camels a man has primary, but not absolute rights of possession. For the camels of the individuals of a dia-paying group (the group who pay collectively the blood money of a clan member) constitute their joint stock wealth as a group". (Lewis, 1961)

Men inherit camels - women's inheritance rights under the Shariah are ignored. There are reasons for this. There is the obligation on men to pay the blood money, to pay the bride wealth in camels, and to provide camels for ritual slaughter on feast days, religious occasions of special significance, and for the important occasions of births, marriages and deaths.

In transferring property rights, the selling of male camels is common, but the selling of female stock is rarely practised, except between the agnates of a sub-clan of a camel breeding group. Among the Afar, exchanges value for a young she-camel is two cows, or 35 sheep and goats.

Occasionally a sub-clan agrees to dispose of the whole of its camel wealth, including breeding stock. This is done when a family becomes thoroughly urbanised, with children in school, and no longer wishes to live as clansmen.

The distribution of usufructuary rights in camels is common, but usually limited to conferring milking privilege on some poor relative. In special cases half of the increase may be given.

The total composition of a clan's camel herd varies greatly. It will be influenced by the need to provide camels to support subsistence flocks of sheep and goats, the number of camels sold, and the effect of stock losses; also a reduction in breeding rate during periods of drought.
A herd, depleted by losses, heavy selling and male-calf slaughter, may have some 60 percent of mature females, 10 percent of mature males (including a herd sire), younger male camels retained as future herd sires, and some castrates. The balance will be 30 percent of immature males and females, including calves. A more favourable situation might show 50 percent mature females, 10 percent mature males, and 40 percent immature males and females.

The cultural and social importance of camels.

Because of its great value and its importance as a means of survival, the camel has become a symbol of prestige, with its ownership surrounded by a special cult and with attendant prohibitions.

Among the principal Somali camel clans, the ownership of camels has been bound with social obligations and contractual arrangements between the clans. The most important is the requirement to pay the blood money in camels, with 100 camels paid for a man's life, and 50 camels for a woman's life. (In recent times blood money payments have been prohibited by the Somali Government). Other payments in camels may be made for damages inflicted on persons.

There are prohibitions. Among most camel owning people of the Horn only boys, unmarried women, or ritually clean men may milk camels. Among the Afar transfer of milk from the vessel into which it has been milked is prohibited; any treatment of milk is forbidden. Women should not approach a new born camel. Menstruating women should not approach a camel giving birth, or the new born camel. Among some clans the camel herd boys may only drink water at the time the camels drink.

Superstitions abound. Among the Somalis, Sunday morning is the correct and lucky time to brand camels. Sterile she-camels which exhibit sexual abnormalities
and grow a long hump (Abeer, Somali) are viewed with suspicion. They will never be sold, but will finally be slaughtered with a reading from the Quran.

Management

The camels of the Horn are range fed. Hand feeding is almost unknown, but camels may be brought to agricultural tracts and there fed off crop residues, such as sorghum stover, cotton stalks, sesame waste and pulse haulms. Burden camels are worked without hand feeding, and the loads and distances travelled, and rest times are adjusted accordingly. This is quite different from the heavy scale of rations (grains, pulses and hay) prescribed for the feeding of camels employed on military service in former times.

The main forage consumed is browse from the trees and shrubs. There are many valuable species. Noteworthy are the Acacias, Salvadoria, Ziziphus, Dobera, Cadaba and Boscia. Forage from low growing shrubs, such as Indigofera and Disperma, as well as from forbs, such as Tribulus, assume great local importance.

At times camels may graze for long periods on grasslands. In parts of Ethiopia and Somalia introduced Opuntias (both valuable and noxious types are present) have colonised large areas, and herds of camels use this as a main source of forage, and thrive on it.

An essential supplement to range feeding is the provision of access to salt vegetation, to salt wells waters, or salt pans, or the feeding of salt or salt earths. This salting is a need particularly emphasized by the great camel owning clans of Central and Northern Somalia, who regard as essential the regular movement to salt vegetation to graze and to salt wells to drink, to become satiated with salt. On salt grazings which are particularly associated with the sea shores, where Sueda is the most important feed, and on the salt flats
and gypseous areas, such as the Nogal valley, camels take their fill of the salty forage and are watered every day, or once every other day. This is possible because the salt areas have surface water supplies in shallow wells, with fresh water overlying the salt water below.

When the camels go to the salt wells every 20 to 60 days (depending on the type of range feed they are on) they stay on the salt wells for two nights and one full day; during this time they are watered several times.

Reference to the old Veterinary Manuals for the use of the Camel Corps of the Colonial forces will show how important the feeding of salt was considered to be. Peck (British Somaliland Veterinary Service) considered a minimum of 140 gm per day necessary. He reported that lack of salt caused skin diseases, such as cutaneous necrosis (Peck, 1939).

There are many variations in methods of herding and management. In the morning the mature camels leave the camp, and the penned camel calves. They spread out over the range, watched over by the herd boys, who have a difficult task in thick bush country. The calves stay nearer the camp, and in the evening they are brought in and penned before the main herd returns.

The control of a large herd of, perhaps, 70 camels spread out in thick shrubland is uncanny. The Somalis may use large wooden clapper bells, slung round the necks of favourite camels, in order to locate the herd. The Afar do not use bells; there is constant hostility with the neighbouring Iise Somali, and with many of their Oromo clan neighbours, and they do not want the sound of clonking camel bells to announce the presence of their herds in the bush.

The camel camp is constructed of a thorn bush fenced enclosure, divided into main compartments for the different owners. Smaller compartments inside may hold
the camel calves. In the centre is an enclosure where the herd boys sleep. There are no huts or shelters. The boys sleep on mats or on cut grass, and shelter under the bellies of the camels when it rains. Apart from weapons (which are important) the only articles kept are the milk pots, and a few short-handled axes for lopping browse.

The herdsman are young men and boys. In a big camp an elder may be present. His duty is to see that the range selected for each move is satisfactory, and that harmony is maintained among the herdsman. The herdsman and the elder are of one agnatic group, and the camels are their clan property, in an extended sense. The food of the herd boys is milk, supplemented with wild fruits and berries. On very special occasions they eat the meat of a slaughtered camel; and in times of great stress, when lacking milk and water, the herdsman may slaughter a camel to survive on the water from the stomach and the tissues of the beast.

The camels are divided into dry herds (Ghanni; Horoween) and milking herds (Irmanee). These, in Somalia, may be held close to camps holding the weaker sheep and goat flocks, or may nowadays be used for the production of milk for sale to some settlement or market centre. Among the Somalis the traditional herding unit is the Kadin of 70 head. The milking is done by boys, unmarried women, or ritually clean men.

It is usual practice to allow two teats for the calf and to milk two teats - these are kept from the calf by tying with soft bark fibre. The milker stands on one leg, puts the milk pot on the upper part of the leg, and milks with one or two hands. The calf may be restrained, or the she camel may be restrained by an attendant, but a good herdsman can usually milk his camels single handed.

Colostrum, which is produced for the first seven days of the lactation, may be shared with the camel calf,
or part milked onto the ground. The herdsmen fear the drinking of too much colostrum by the calf.

The main milking times are once before dawn (but sometimes after daylight) and again at night, some two hours after penning the herds. Milking may take place at other times and, in the case of a she camel which has lost her calf, she may be milked a total of 5 to 7 times, according to her milk yield.

The amount of milk taken will depend on the milk-yielding capacity of the she camel, the amount allowed for the calf, length of lactation, and, of course, the forage availability and water. On the average it is likely that 1 800 lt are taken in a lactation of 365 days, with about 9 lt daily at the peak and with good forage conditions. A twelve month lactation is the rule, but if not in-calf again the she camel may milk for a second year.

Most of the milk is drunk fresh. Somalia customs differ. Milk may be drunk fresh, slightly sour, or strongly soured. In the South it may be sold and drunk sweetened with sugar.

In addition to the two herds mentioned above, there are the camels which support the so-called weak subsis-tence flocks of sheep and goats, which may be combined with a cattle herd within one camp. The small stock are looked after by the women and children, mainly the girls. In dry country they will be supported by two burden camels and one or two milch camels. Camel milk will supplement the sheep and goat milk, and allow their milk to be used for making ghee. In the dry season the ewes of the famous Blackhead sheep, kept by the Somalis, will be dry, as they are seasonally bred, and once only. The she goats are more reliable for milk, and they are bred at all times throughout the year. In drier, hotter country the goats in a combined flock will outnumber the sheep.
The burden camels are used to bring in water and rations to the camp, and these and the milch camels graze near to the camp and are hobbled. They go to water when water is drawn, or when the small stock go to water. Under this treatment their forage intake is inferior to that of the main herds, and from time to time they may need to be changed for other animals drawn from the main herds.

Breeding

The selection of a herd sire is a matter of great importance. The males are left entire for as long as possible. As they mature they start to fight, and it is from the most strong and aggressive males that the herd sire prospects are chosen. Those animals not chosen will be castrated. The selected male may have to wait his time while dominated by an older and stronger herd sire. He may be entered for service gradually, and be fully active at seven years, and remain serviceable for another seven years. At his prime he will head a herd of up to 100 females, but generally he will head a Kadin strength of perhaps 40 females.

The females are culled for defects, such as slow breeding, poor milk yield, bad mothering, or production of weakly offspring. The environment and its periodic droughts ensure that only the hardiest and most enduring will survive.

Those animals culled will go for slaughter. Young barren females provide the most prized slaughter animals. In the Horn culled females are eaten locally (there is a ban on the export of females). Fattened males usually go for export.

The she camels calve for the first time about the 5th or 6th year. But the Afar tend to calve their camels earlier than the Somalis. They will continue to breed until in their twenties, calving every two years, unless upset by a major drought, disease, or other calamity.
In the Horn the male comes into season following the Spring rains, and the flush of vegetation causes a rise in his condition. The Rut (Quoq, Som.) may last for several months, and there may be a return following the second rainy season. With a rise in condition, the females are in oestrus at regular intervals. A strong male will round-up and exhaust a female, and crouch her and serve. Hand service, with assistance from the herdsman well-known to the stallion, is also common; this method is used to select a female to be served, and she is usually served twice.

Somalis believe that if the she camel is crouched, and struck with a stick, she will cry "AHAA" if not pregnant. If pregnant, and led in front of the stallion, she will lift her tail.

Gestation is reckoned to be 380 days. Parturition is uncomplicated. Twinning is very rare. After calving the she camel may be restrained with her calf, so that she will mother it correctly. Mothering and acceptance of an orphan calf may be encouraged by tying the calf in front of the she camel and then attaching a neck rope from the calf to the mother's lip.

Production

If her own calf dies, the she camel may be taught to milk by offering her a piece of the neck skin from the calf. In the past it has been common practice to slaughter the first male calf born to a camel heifer in order to teach her to milk without a calf at heel. At milking the calf skin is placed in front of her and she is called by name (all she camels are given names), her teats may be massaged lightly, and she should then let down her milk.

A camel refusing to milk may be tied up short for several hours. Her udder may then be massaged, and after this she is released, and milking attempted. Another
system is to use the vagina clamp (the Qualoch of the Somalis). This is a split stick which is used to clamp the vulva, while the animal is tied up short (head to tail). On release of the clamp, and when untied, the she camel should let down her milk. It may be noted that other devices, such as vagina blowing, used on cattle to induce letdown, are never attempted on camels.

At nine to eleven months of age the camel calf is weaned. This can be done by denying milk through tying up the mother's teats which were formerly left for the calf - or the calf will be fitted with a leather noseband, through which strong thorns are made to protrude, with the sharp points outwards. With this arrangement the dam will be pricked if the calf attempts to suck, and she will drive the calf from her.

There are several methods of emasculature. The testes may be drawn, or the cord may be cut, and then cauterised and powdered over with ash. The cord is sometimes tied above the cut. Losses from these operations are considered negligible.

Because the camels are always with their herdsmen and are handled from birth, there is little difficulty in training. The usual form of restraint is to seize the upper lip by hand, the camel is then crouched and fitted with a neck rope and a lighter rope with a loop which is placed over the lower jaw. The camel is then tied to a tree. After being tied for some time, he is released, and led out to follow his companions. He may be hobbled. This leading excercise continues, and he is taught to crouch and rise on command. Finally, a pad, and then saddle equipment are put on him and, after becoming accustomed to the feel of it, he is loaded lightly. The whole operation takes about a week. Saddle training is more complicated: mounting of the rider on to the crouched camel, rising with the mounted rider, crouching with the rider mounted, all are practised with the words of command. The walk, and the run at various paces, are taught and practised.
In the Horn, male camels only are worked. Training may start quite early with the Afar, who train and work their young males (lightly loaded) and market them when well-grown. The usual age for training is between the 4th and 5th year.

Branding is done with the hot iron (Madden, Som.). The brand is placed on the upper part of the neck. The brand (Sumad, Som.) will be a clan brand and not that of an individual.

In the Somali system of slaughter, the camel is crouched, with the forelegs hobbled. A hole is dug to catch the blood. The head is pulled down (by the nose hold) over the hole, and the neck is pierced with a spear thrust. The animal is then bled.

In the Afar system of slaughter, the beast is crouched (it may be hobbled). The head is pulled forward and is then held down by a stout stick placed across the lower jaw and behind the tushes. Two men hold the stick down and a dagger (Gille, Af.) is drawn across the neck, severing the blood vessels.

The animal is not flayed to remove the skin in one piece. Instead, after removal of the offal and the extremeties, large sections of the carcase (quarters, loin, back, brisket, etc.) are cut from the carcase, with the skin adhering. The skin is then flayed from these portions. Camel hides are used in local leather works, and particularly for sandal making.

The meat cuts in order of importance are: Brisket, Hump, Ribs, Loin and other portions. The Afar prefer to eat the hump raw, but this must be while the flesh is still warm. If the hump meat cools off, it is boiled before eating. A favourite method for preserving camel meat is to dry it in strips, which are then cut into small sections and preserved in clarified butter.

One remarkable omission in the Horn is the failure
to make use of camel hair. Although hair production in hot climates may be far less than in the cold climates, the annual yield of camel hair might average 0.5 kg per animal. The value of this from over four million camels would be of considerable economic importance. However, it is certain that great prejudice would have to be overcome before the camel owners could be persuaded to clip, or pull the hair from their animals.

The draught camel

In the agricultural zones of North West Somalia and bordering Ethiopia, camels may be used for field work. A single camel, with trace type harness, is hitched to the common chisel type plough, with the pole draught attachment but, to accommodate the trace attachment instead of the yoke, the pole draught is shortened. The camel is usually led, and on light land the work performed is equal to that from a yoke of oxen.

Marketing

The traditional markets are for the sale of animals for slaughter, and for the sale of male camels for pack use. The most important development in recent years has been the export of live animals for slaughter. (Table 1) This has followed the rise in wealth of the oil-rich states of Arabia, and the development of port and road transport facilities.

Almost all camels exported form the Horn go by sea to the port of Jidda in Saudi Arabia. From this port live camels are transported by motor vehicles to interior markets.

Only male animals are allowed to go for export. As a result, competition for available supplies of male camels is intense.
The traditional local markets supply those pastoral and mixed farming communities who need burden camels, but do not themselves breed camels. Examples of this are seen in the supply of burden camels by the Gabra to their neighbours (and hosts), the Boran cattle breeders; the sale of camels by the Afar to their western Oromo neighbours; and for the needs of the great salt caravan trade, which carries salt from Dalol to the market centre of Makalle, in Tigre. Because of the competition, there is a tendency to use far too many young animals for pack work. Younger, lighter-weight animals now go for export.

To supply this insatiable demand, camels are drawn from all parts of the Horn to the great market centres, with the main stream of export animals going to the port of Berbera, on the northern coast of Somalia.

There are problems in the shipping of camels. Their loading and unloading is not easy, and they succumb more quickly than other livestock when subjected to stress. In former times losses on the sea journey of some 80 hours between Berbera and Jidda could be as heavy as 15 percent. Great efforts made by the Government of Somalia, through its Livestock Development Agency, in the past twelve years has reduced shipping losses to acceptable levels in all classes of livestock exported.

Losses

These can be divided into three main groups. First, losses through theft. Second, losses through predation. Third, losses through disease and injury.

For the stock thief and inter-tribal raider, the theft of camels is the most prestigious exploit. Apart from the value of the loot, it is an affront to one's opponent. Thefts can take place at any time, but inter-clan or inter-tribal friction puts the camel herds at constant risk. Camels are then guarded more closely. Armed men are always nearby, and the herds may be brought
closer together, or into a large camp, as a defensive position (such as the "Gaanda" of the Afar).

Losses from predation are serious. Animals which have strayed, or which have been left out in the bush are at constant risk. The main culprit is the hyaena. In some areas, particularly those where the wildlife has been destroyed, any camel left out is likely to be devoured. Many camel owners claim that half their losses in young stock are from predation.

In the Horn losses from disease are serious. Modern methods of treatment for certain diseases are satisfactory, but many other conditions require investigation and determination of methods for control.

The most serious losses concern infant camels and the age group to one year old. Losses, reported to be as high as 25 percent, are mainly due to intestinal disorders. Recent work in Ethiopia has shown *coli bacillosis* and *Salmonella* infections to be the cause. Treatment with sulfa compounds has been effective, but further investigation is required.

The widespread incidence of camel trypanosomiasis is a cause of constant loss, but this can now be effectively treated. Camel mange, equally widespread, can also be controlled. Vaccination against anthrax is effective. Camel pox is particularly a disease of young camels, six months to two years of age, and death may be the result.

*Helminthiasis* is serious in camels, and investigational work in Ethiopia has shown that a large proportion of camels suffering from trypanosomiasis carry a heavy worm burden, which requires treatment.

Improvement of camel production in the Horn of Africa

The obvious and most immediate needs are for improved
range management practices, and for attention to the prevention of losses through predation and animal diseases.

In range management there should be rigid enforcement of rules to prevent private development of water supplies, except within a range development plan. Government agencies should not embark on any range water development plan without the safeguards against range depletion through overstocking, sedentary occupation or cultivation.

Range management systems should be imposed on all areas to conserve forage and water for dry season use. In certain situations consideration should be given to the allocation of selected areas to be preserved as camel ranges.

Predator control should be undertaken with correct safeguards for other wildlife. Investigation of camel diseases should be undertaken with special reference to prevention of losses in infant and juvenile camels. Organization of veterinary services to train a corps of Veterinary Scouts elected by their own camel owning clans should be established, to work in the nomadic environment, with special attention to camels.

Governments and Development Agencies should introduce and support camel production investigational work and improvement schemes.

Where riding camels are not used, there should be a determined effort to introduce them and to use this method of transport as an energy saving measure.
Table 1: Camel exports

<table>
<thead>
<tr>
<th>Somalia</th>
<th>Year</th>
<th>Number</th>
<th>Average value per head</th>
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<tr>
<td></td>
<td>1972</td>
<td>21 954</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1973</td>
<td>28 759</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1974</td>
<td>23 965</td>
<td>1 100 to 1 200 Som Sh</td>
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<td></td>
<td>1975</td>
<td>34 223</td>
<td>1 200 to 1 300 &quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td></td>
<td>1 500 to 2 000 &quot; &quot;</td>
</tr>
</tbody>
</table>

(Source: Somalia Trade Figures)

Ethiopia

<table>
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<tr>
<th>Year</th>
<th>Number</th>
<th>Average</th>
<th>Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>2 540</td>
<td>296.21</td>
<td>$ Eth.</td>
</tr>
<tr>
<td>1975</td>
<td>5 935</td>
<td>540.79</td>
<td>$ Eth.</td>
</tr>
</tbody>
</table>

(Source: Ethiopian Customs Head Office)

REFERENCES


Peck, E. 1939 British Somaliland Veterinary Service Report

Peck, E. 1939 Salt intake in relation to cutaneous necrosis and arthritis of one-humped camels (Camelus dromedarius L.) in British Somaliland. Vet. Rec. 51 (46) 1355-1360

Lewis, I.M. 1961 A pastoral democracy. Oxford University Press
THE BACTRIAN CAMEL OF CHINA

Dong Wei

Summary

The camels of China are the two-humped species, *Camelus bactrianus*. The total population is approximately 600,000, distributed in Inner Mongolia, Xinjiang and other provinces. They are 170 - 180 cm in height, weighing 400 - 600 kg, with light brown or brown coat color, strong conformation and good working ability. In desert areas they are important pack animals and also used for riding, as draught animals, and for wool production. Camel wool is a high-quality fibre. The annual production is about 3 - 4 kg per head. The national yield is 1,500 tons per year, of which 600 to 800 tons are exported. Meat and milk production are relatively unimportant.

Population and distribution

Owing to the great variety of geographic environments and natural conditions, the People's Republic of China has numerous species of domestic animals, including specific ecotypes with relatively small populations which live in vast areas but with specific climatic conditions, e.g. the camels, which thrive in the deserts, semideserts and steppes; and the yaks, which are found only in Tibet, on the world's highest plateau, the Qinghai Xizang which has an altitude of over 3,000 metres.

Chinese camels belong to the Bactrian type (*Camelus bactrianus*), which are mainly distributed in the Autonomous Regions of Inner Mongolia and Xinjiang. The total population is about 600,000, 60 percent of which are in Inner Mongolia; there are 160,000 (26.6 percent) in one administrative division alone, the Alxa Banner, that is an average of 1.5 camels per square km, or to each human pastoral inhabitant.
The distribution zone is around 40° north latitude with a total area of over one million square km at an altitude of over 1,000 metres (Figure 1). The environment is harsh and rigorous consisting mostly of deserts, semideserts and arid grasslands. Sand dunes are common as in the Gobi Desert. The climate is typically continental and extremely dry, with an annual precipitation of around 100 mm. Surface water is scanty and sand-carrying winds are frequent. Daily and annual temperature variation is great. It is bitterly cold in winter with a minimum temperature below -30°C; in summer the air temperature may reach above 42°C, while on the surface it may be over 60°C. Generally, the annual average temperature is significantly lower than that of the areas inhabited by the one-humped dromedary camel in North Africa and West Asia. The vegetative cover is very thin and consists mostly of low shrubs, scrub, halophytes, sand-tolerant plants and low quality herbs.

Economical value

In China, camels are esteemed as "the ships of the desert" for their capacity for desert travel. In addition, they provide such valuable products as wool, meat and milk. The primary purpose of camel husbandry varies from one region to another.

Camels in China may be used for transport and as draught animals. The use of vehicles is not practicable under desert conditions so they are most commonly used as pack animals. In some areas large numbers of camels are organized by transport cooperatives and provide the principal source of income of some of the People's Communes. In certain areas most farm operations are performed by camels. Travel in the pastoral areas is mostly by riding camel. (Plates 1, 2, 3.)

The production of camel wool in China is estimated at approximately 1,500 tons per year, of which 600 to 800 tons are exported, constituting 12 - 16 percent of
the total volume of the world's camel wool trade. The wool is used as padded cloth, quilts and mattresses and as a valuable textile. (Plate 4.)

The meat and milk of the camel are secondary in importance to wool production and work ability, but as usage for power decreases it appears likely that the importance of the camel as a source of meat and milk will receive increasing emphasis.

An important aspect of the economic significance of camel raising in China lies in the fact that the animal has a remarkable conversion ability and can utilize plants other domestic animals cannot assimilate, and convert them into meat and milk and work output. Moreover, camel husbandry entails little maintenance cost; management is simple, and there is a notable ability to resist unfavourable conditions.

Conformation and appearance

Chinese camels are strong in constitution, with well developed musculature and a height of 170 to 180 cm. The body length and heart girth are around 85 percent and 120 percent of the height respectively. Physical measurements of camels in different parts of China are shown in Table 1. (Plates 5, 6, 7.)

Chinese two-humped camels are leggy with fine head, long neck and sloping croup. The two humps are 20 – 40 cm high, their size and shape varying with the amount of fat deposited within them. The size of the humps is related to the physical condition and the quality of the vegetation. When feed is plentiful, and the fat stock is high they are firm and erect as is commonly seen in late summer and autumn. During the late winter and early spring when the pasture is scant and poor the fat reserve is exhausted and the humps collapse like empty bags. The humps may be considered as an energy bank and an indicator of nutritional condition.
The coat colour of the Chinese camel is generally light brown or brown, but dark-red and white types are occasionally seen. Camel hair fibers may be classed as three forms, long hair, hair and wool or down. Long hair grows on the top of head along the upper and lower borders of the neck, on the elbows and the tops of the humps, and the tail switch. They are 30 cm or more in length on the neck, shorter in other parts. The wool undercoat is 4 - 7 cm thick and covers the whole body, forming a soft downy layer, within it stand sparse hairs of 7 - 10 cm in length. (Plate 4.)

Growth rate

The bactrian camel grows and develops slower than other domestic animals. Puberty occurs at the age of 3 to 4 years. Physical development continues until the age of 6 to 7.

The body measurements of newborn calves are shown in Table 2. Table 3 presents measurements of female camels at various ages, from which the general growth rate can be noted.

The figures in Table 3 indicate that the camel grows very rapidly in the first year; the heart girth, which is only about 60 percent of the height at birth, exceeds the latter as early as the sixth month. From the second year of life the growth rate becomes progressively slower.

Pasturing and management

Camels propagate naturally and live under semi-wild conditions, roaming and grazing on range all the year round, without any supplementary feeding and, except for the special working animals, without housing. They graze and browse without discrimination.

Camels under such conditions generally drink once
per day, or every other day but if water is lacking they can endure for 6 to 7 days without drinking. It must be stressed that ready access to salt is vitally necessary to wellbeing.

Generally, females and castrates are maintained in separate herds, each numbering 80 - 120 animals. The female herd includes reproductive females, 1 to 2 year old calves, and one or two sires; the other herd consists of castrates, 3 to 4 year old males and culled females. No herdsman are needed to tend the herd. The herd is customarily inspected every 2 to 3 days, but greater care is exercised in winter and early spring, when breeding and calving take place.

When the camel comes to moult from April to June the wool is hand-stripped. This must be done promptly in order to avoid loss. Long hairs are sheared before shedding takes place.

Females are bred generally when 3 to 4 years old, and the reproductive life may last to 20 years of age. Usually they give birth once every two years. Males used for breeding start service at 5 years of age, and cease at around 15 years of age.

For convenience of handling, young camels have a wooden nose-bar inserted below the nostrils at 2 to 3 years of age (similar to the nose-ring of the bull). Young males not used for breeding are castrated at 4 to 5 years of age. Both the insertion of the nose-bar and castration are carried out in the autumn.

Training of camels to work is done when they are 3 to 4 years old. The castrated camels may go on working until 25 years of age. Pregnant females undertake light work, but nursing camels must not be used for power. Mostly, winter and spring are the working seasons, while in summer and autumn they are allowed to graze day and night on pastures to restore physical condition and permit of the accumulation of nutrients in body tissues.
Productivity

The principal significance of camel raising in China is the provision of work output, and for the wool. The production of meat and milk is of secondary importance.

Camels are mainly used as beasts of burden. They are capable of traversing the wide, waterless grass-deficient desert areas such as the Gobi, travelling long distances persistently and continuously without eating and drinking for days on end. Their endurance and tenacity have made them the sole means of transport and traffic in those desert regions throughout history. Even in the future it is unlikely that modern means of transportation will cause them to be replaced entirely. It is not surprising to note that, even in the 20th century, the camel teams are still seen in the barren lands and among the sand dunes of the north-western China, just as the camel caravans marched on the Silk Road in ancient times.

Most of the working camels are castrates but non-pregnant females are also employed. Camels begin to be used at around 4 years of age for carrying light loads of 50 - 100 kg, the burden being increased gradually with age. The normal load is around 40 percent of the liveweight, i.e. 150 to 200 kg with a maximum of 250 kg. Carrying its load, the camel can cover 35 - 40 km within 24 hours.

Riding camels are common in the deserts. Though not as fast as a horse the camel is a more comfortable ride. It usually maintains a speed of 5 - 8 km per hour in summer and autumn, and 7 - 10 km in winter and spring.

In long-distance travel it can cover 30 - 40 km per day for a month on end, while for high speed, short distance travel it will cover 70 - 80 km per day for 2 to 3 days. The maximum distance possible in one day is 120 km.

The draught power of one camel is equal to that of
two Chinese ponies or two oxen. It can pull a load of one ton, and can plough 0.2 hectare of land in 8 hours.

Camel wool is a superior fiber which is soft and elastic and has good insulation property. Three to four kg (not including long hair) may be collected per head, the maximum yield being over 6 kg. The highest yield is obtained at 7 to 10 years of age. The wool yield of the male is 30 percent more than that of the female. The scouring yield of camel wool (i.e. percentage of net wool) is generally over 70 percent. One to three kg of long hair may be shorn per head every year. (Plate 3.) The long hair as well as the hair in the wool coat are usually used for household articles such as cushions, mattresses, bags and ropes.

The characteristics of camel wool are shown in Table 4.

The data in Table 4 indicate that not all the indices of the wool of males are superior, while the quality of the wool of the young camel is best. Generally speaking, the fineness of camel wool is similar to that of the sheep but it is less dense, shorter in length and with fewer scales; the crimps are irregular and the diameter of the individual fibre is uneven, so that its spinning quality is inferior to sheep wool.

Wool fibres from different parts of the body vary greatly. The longest, finest, densest fibres are from the shoulder. On analysis it can be noted that the nutritional level has a direct influence on wool growth. The number of wool fibres per cm$^2$ of skin of a camel in good physical condition is 4 200 - 4 500, while the number in an animal in poor condition is only a half of this figure. Camels raised in different regions of the country possess different wool characteristics.

In general, camels are not so good for meat purposes, since their economic importance lies in their working value and wool production. Only those which lose their
working ability or become sterile are slaughtered. The results of two slaughter experiments are presented in Table 5.

In certain pastoral areas, camels are also used for milk production. In addition to the milk taken by the sucking calf, there is a yield of 0.5 - 2.0 kg per day. The lactation period lasts 14 to 16 months, and its peak occurs in the 3rd or 4th month after parturition.

Conclusions

Camel husbandry is a minor and neglected sector of animal production in China. Camel rearing, however, appears to be effective and rational in utilizing local plant resources in the extensive sterile and arid areas in north-western China, since other farm animals cannot adapt to the natural conditions. Even though the importance of the working camel in some districts will decrease in the future as modern means of transport are extended, the potential of camel production, especially for wool and meat, should not be neglected. Therefore, the present primitive systems of husbandry should be improved as a natural course of development, and production should be stimulated. It is necessary to intensify scientific investigation, to formulate an improvement program, establish specific types and breeds, improve management, raise productivity and increase the output of utility camel products.

BIBLIOGRAPHY (texts in Chinese)


1964 Animal production in Zinjiang, Academic Press
Liang Chao-lu: Analysis of the wool coat of the camel (Unpublished)

Shui Shi-vong. 1979. Advantages of camel raising. Inner Mongolian Animal and Veterinary Sciences, No. 2

Table 1: Body measurements of adult Chinese camels (cm)

<table>
<thead>
<tr>
<th>Sex</th>
<th>Location</th>
<th>Number measured</th>
<th>Height</th>
<th>Length</th>
<th>Heart girth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1</td>
<td>4</td>
<td>178.0</td>
<td>155.7</td>
<td>219.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>20</td>
<td>185.8</td>
<td>169.4</td>
<td>232.3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>180.3</td>
<td>160.0</td>
<td>243.3</td>
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<tr>
<td></td>
<td>4</td>
<td>24</td>
<td>170.7</td>
<td>141.0</td>
<td>204.0</td>
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<td></td>
<td>5</td>
<td>40</td>
<td>181.3</td>
<td>152.4</td>
<td>215.9</td>
</tr>
<tr>
<td></td>
<td>Total/average</td>
<td>91</td>
<td>179.3</td>
<td>153.5</td>
<td>217.4</td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
<td>62</td>
<td>176.9</td>
<td>154.5</td>
<td>227.4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>13</td>
<td>176.8</td>
<td>155.9</td>
<td>221.2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>11</td>
<td>173.6</td>
<td>151.7</td>
<td>232.5</td>
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<tr>
<td></td>
<td>4</td>
<td>531</td>
<td>168.3</td>
<td>143.0</td>
<td>200.9</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>64</td>
<td>173.9</td>
<td>147.5</td>
<td>209.6</td>
</tr>
<tr>
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<td>48</td>
<td>166.0</td>
<td>144.9</td>
<td>211.3</td>
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<tr>
<td></td>
<td>Total/average</td>
<td>729</td>
<td>169.6</td>
<td>144.9</td>
<td>205.4</td>
</tr>
<tr>
<td>Cast-rate</td>
<td>3</td>
<td>12</td>
<td>179.3</td>
<td>163.8</td>
<td>245.0</td>
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<td>274</td>
<td>176.6</td>
<td>143.6</td>
<td>208.5</td>
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<td></td>
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<td>19</td>
<td>180.0</td>
<td>155.2</td>
<td>220.1</td>
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<td></td>
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<td>Total/average</td>
<td>331</td>
<td>176.5</td>
<td>145.7</td>
<td>211.4</td>
</tr>
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</table>

Table 2: Measurements and birth weights of newborn calves

<table>
<thead>
<tr>
<th>Sex</th>
<th>Height cm</th>
<th>Length cm</th>
<th>Heart. girth (cm)</th>
<th>Weight kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>98.1</td>
<td>61.3</td>
<td>77.1</td>
<td>34.9</td>
</tr>
<tr>
<td>Female</td>
<td>95.7</td>
<td>58.1</td>
<td>74.0</td>
<td>31.7</td>
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</table>
Table 3: Measurements of female camels at various ages (cm)

<table>
<thead>
<tr>
<th>Month</th>
<th>Height</th>
<th>Heart girth</th>
</tr>
</thead>
<tbody>
<tr>
<td>birth</td>
<td>95.7</td>
<td>58.1</td>
</tr>
<tr>
<td>1</td>
<td>109.0</td>
<td>98.8</td>
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<tr>
<td>2</td>
<td>119.8</td>
<td>109.1</td>
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<tr>
<td>3</td>
<td>122.3</td>
<td>115.5</td>
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<tr>
<td>4-7</td>
<td>132.2</td>
<td>138.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>138.9</td>
<td>146.8</td>
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<td>2</td>
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<td>164.2</td>
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<td>204.0</td>
</tr>
<tr>
<td>6</td>
<td>169.6</td>
<td>203.5</td>
</tr>
</tbody>
</table>

Table 4: Wool properties of Chinese camels

<table>
<thead>
<tr>
<th></th>
<th>Adult male</th>
<th>Adult Female</th>
<th>Castrate</th>
<th>Young</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of wool coat (cm)</td>
<td>4.27</td>
<td>4.88</td>
<td>--</td>
<td>5.63 (♂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.71 (♀)</td>
</tr>
<tr>
<td>Stretched length (cm)</td>
<td>6.82</td>
<td>8.85</td>
<td>--</td>
<td>7.86 (♂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.53 (♀)</td>
</tr>
<tr>
<td>Diameter (microns)</td>
<td>18.3</td>
<td>14.7</td>
<td>14.9</td>
<td>14.8</td>
</tr>
<tr>
<td>Density (No of fibres per cm²)</td>
<td>2730</td>
<td>3205</td>
<td>3201</td>
<td>4522</td>
</tr>
<tr>
<td>Percentage of wool fibres in coat</td>
<td>76.3</td>
<td>79.2</td>
<td>83.6</td>
<td>88.3</td>
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</tbody>
</table>

Table 5: Meat production from Chinese camels

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Number Slaughtered</th>
<th>Live Weight kg</th>
<th>Carcass Weight kg</th>
<th>Dressing Percentage %</th>
<th>Weight Net Meat kg</th>
<th>Percentage of Net Meat %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6ᵃ</td>
<td>727</td>
<td>257</td>
<td>35.4</td>
<td>206</td>
<td>28.3</td>
</tr>
<tr>
<td>2</td>
<td>16ᵇ</td>
<td>407</td>
<td>207</td>
<td>51.7</td>
<td>145ᶜ</td>
<td>35.7</td>
</tr>
</tbody>
</table>

Notes:  
a. Four females and two castrates  
b. Five females and eleven castrates  
c. Includes fat.
Figure 1: Distribution area (shade) of Chinese camels.

Plate 1: A camel team in Alxa, Inner Mongolia
Plate 2: A camel with riding saddle.

Plate 3: Loaded camel. Alxa, Inner Mongolia
Plate 4: This superior camel male yields 5 kg of hair and 6 kg of wool per year.

Plate 5: Male camel, 4 years old.
Plate 6: Female camel, 9 years old.

Plate 7: Castrate camel, 9 years old.
THE CAMELIDAE OF SOUTH AMERICA

A. Victor Bustinza Choque

SUMMARY

Many thousands of years ago camelids came from North America to the high altiplano regions of Peru, Bolivia, Argentina and Chile. They were domestic animals in Incan times but the excellent management systems turned to disaster with the arrival of the conquistadores in the 16th century. Only now has the stage been reached when camelid industry is progressing industrially and scientifically.

The graceful vicuña (*Vicugna vicugna*) produces one of the finest fibres in the world and both the wool and the skin are highly prized. The guanaco (*Lama guanicoe*) has adapted to life in coastal areas, in the forests and in the high mountains. The skin is very valuable. The llama (*Lama glama*) was the first of the camelids to be domesticated. It is still used as a beast of burden and is also a valuable source of meat and fibre. It is an object of religious significance. The Huacaya and Suri breeds of alpaca yield quality meat and produce a fibre which has a high value on the world market. The camelids of the New World do not have humps.

This unique species has a great productive future, but many avenues have yet to be explored in science, technology and sociology.

ORIGIN

There is an abundant literature concerning the remote past of the camelids that indicates clearly that they originated in North America.

The first genus of camel was classified as *Protylopus*
petersoni. This fossil was found in the Cordillera near Utah, USA. From this first genus evolved the two most important genera, Prohebrotherium and Gomphotherium. The first had two species: P. labiatum which was the size of a sheep and looked a little like the modern day llama. The second species was P. wilsoni which soon became extinct. It was from the first appearance of these procamelus that gave the origin to the most notable species, the Camelop and the Tamupolama. Those two were to be the original form of the camels of Asia and South America respectively. With the coming of the ice age the camelid species migrated. One group moved via the Bering Strait to arrive on the continent of Asia (these became the pre-camelid of the Orient or Asia) and the other, by the Panama Isthmus to South America, migrating as far as Peru, Bolivia and Argentina. All this took place approximately one million years ago.

There are four distinct types of fossils of South American camelids: Eulamaops, Paleolama, Lama and Vicugna. The first two are extinct but the others still exist. The genus Lama had five species but today only three remain: Lama glama (Llama), Lama pacos (alpaca), and Lama guanicoe (Guanaco); the genus Vicugna had only one species and this still exists, Vicugna vicugna (Vicuna).

HISTORY

In pre-Inca times, from Ecuador to the mountains of Santa Cruz around the years 3 500 to 5 000 years B.C. the appearance of agriculture and domestication became a reality. In the Altiplano of Bolivia and Peru this took place around 4 000 B.C. It is likely that about this time the domestication of the llama took place. However, the domestication of the alpaca did not come about until 500 B.C.
At the time of the Incas

The domestic camels played an integral part in the economical, sociological and religious activities of the pre-Inca and Inca civilizations.

The Incas had a special group of people organized specifically to tend the animals. Individuals were given various responsibilities such as selection, reproduction, industrialization, health, control of production, and selection and formation of herds and pastures.

The hunting of wild animals was permitted during certain times of the year to obtain wool and meat and to eliminate those animals that were diseased and old. The killing of these wild animals was as a form of recreation. They were also used as sacrifices for religious purposes or veneration to the sun and moon gods.

During the reign of the conquistadores

The Inca civilization exploited the camels by managing both domesticated and wild animals. However, this excellent management system disappeared with the arrival of the Spanish conquistadores.

The first Spanish conquerers of Peru abused not only the people but also the native camels. All management techniques developed by the Incas were ignored and the herds quickly degenerated. Llamas for example were misused in transporting minerals and were inadequately fed and tended. Husbandry went from sophistication to incapacity in a very short period of time, and extermination became imminent. At this point the colonial authorities became alarmed and proceeded to enact laws to save the camel from virtual extermination.

Mining was the primary occupation and the position of the South American camels changed very little over the centuries. However, soon after the advent of the
Republican system, laws came into existence which prohibited hunting, exploitation and exportation. In 1917 a central experimental station was established in Peru, called La Granja Modelo de Puno, and another in 1950 at the high mountain pass, La Raya. In Bolivia, a further attempt was made to establish an institute at Oruro. Investigations were begun into health, reproduction, management and production. Considerable scientific information has become available but many problems still remain to be solved in relation to these unique camelids.
HABITAT: THE HIGH ANDES

At various times there have been exportations of camelids to other parts of the world. They exist in significant numbers, however, only in Peru, Bolivia, Chile and Argentina.

Along the Western Border of South America runs the high mountain chain, Cordillera de los Andes, or simply the Andes, which runs from Venezuela to Tierra del Fuego in Argentina. In the northern part deep valleys run between the mountains. Toward the central area around latitude 14°, there is an extensive high plateau zone, the Altiplano. Between Peru and Bolivia is Lake Titicaca and, in Bolivia, Lake Poopó. The height of the plateau is between 3 600 and 3 800 metres above sea level. It is 800 km long and 130 km wide and it is here that we find the predominant crops of the Andes: quinoa, barley, potatoes, and oca. The vegetation is native tussock grass.

Above 4 100 meters to approximately 5 500 meters is the area called the High Andes or Montanas Altas. This zone is very abrupt in its geography and suffers from some soil erosion. The vegetation is short tough native grasses of a low nutritive value. The average temperature during the day is between 0°C and 6°C. During the winter temperature can drop to minus 18°C. However, in the summer day temperatures reach over 20°C. Frosts are severe almost all the year around; however, day temperatures can be quite high. It is a climate of extremes. There is abundant rainfall during the summer, averaging between 500 and 900 mm per year. The rains are accompanied by snow and hail. Because of these extreme conditions, both climatic and geographic, there is little or no agriculture in this zone and therefore it is almost solely reserved for camelids, especially for the vicuña and the alpaca.

Each Camelid species has a definite distribution within the Altiplano zone. The llama is found from Central
Peru to Bolivia, whereas the alpaca and the vicuna are found from southern Peru to the northern parts of Chile and Argentina. The guanaco can be found in southern Peru, Chile and Argentina, the major population being located in Patagonia.

The most densely populated Camelid area is around Lake Titicaca and Lake Poопó.

GENERAL CHARACTERISTICS OF THE SOUTH AMERICAN CAMELIDS

The biology, physiology and sociological characteristics of the camels explain their adaptation to the environment.

1. They sleep and defecate in well-defined areas, and they will not graze in these areas. They also have specific places in which they take dust baths.

2. They have a highly defined social structure, and can become very furious when they are aroused. They will attack with their feet and can inflict serious wounds. They spit violently and accurately when they feel threatened.

3. They demonstrate great curiosity for anything that is unusual and will advance fearlessly to investigate the object of their curiosity.

4. They sleep during the night and eat during the day and ruminate mostly in the afternoon and early evening.

5. They have a particular greeting call (challido) although the type of noise differs between species and can change according to the reason for the call.

6. Camelids have an adaptive foot adaptation in the form of a pad or cushion which enables them to
travel over sandy and rough terrain and steep moun-
tainous areas with ease.

7. Females tend to give birth during daylight hours and at intense sunlight and greatest warmth, i.e. 7 a.m. to 12 p.m.

8. The upper lip is bifid. The lower incisors are very sharp and grow continuously. This mouth forma-
tion enables camels to graze short tough lignous pastures.

9. The hair coat is thick. Fibres grow close together providing protection against the cold temperatures of high altitudes. The coat colour provides camouflage in the natural habitat.

10. The number of red blood corpuscles is high (14 million per cubic millimeter). This is to compen-
sate for the low air pressure of high altitudes.

11. They have 37 pairs of chromosomes.

12. It is possible to cross-breed all types of South American camelids, and all crosses are fertile. The most common cross is between the alpaca and the llama which is called huarizo. The alpaca/ vicuña cross is pacovicuña; and the llama and the vicuña cross is the llamo-vicuña. The best cross is said to be the pacovicuña. In the second generation they loose their phenotype.

13. Ovulation is induced by stimulation and the implantation of ova takes place in the left uterine horn. The gestation period is approximately 11 months.

14. The wild species live in social communities of family groups, the family consisting of one male and his harem of females. Another type of group consisting of males is called a tropilla.
SPECIES

Guanaco

This wild species has extraordinary faculties of adaptation. They thrive in coastal areas, in the forests and at high altitudes. They exist mainly in the valleys of Patagonia, Magallanes and down to Tierra del Fuego. Very few are found in the mountains of Peru and Bolivia. (Plate 1)

The guanaco has the same body size as the llama. The whole body is covered in wool of which there are two types: the fibres of the undercoat are very fine and light brown in colour. The fibres of the outer fleece are longer and coarser, and the colour shades to a reddish brown. The head is covered in short blackish hair. The young (chuelengo) of the species has a very fine pelt and is sold mainly for export.

The animal is sought by hunters (chulengueros). The valuable skin is used for coats and other items of clothing, and shoes, bags, belts and other leather articles. The meat is of good quality, and small quantities are exported as a delicacy.

Vicuña

This wild species is found in the High Andes of southern Peru and Bolivia and the northern parts of Argentina and Chile. Most vicuña are protected and are held in large parks or reserves, and in some extensive fenced areas, e.g. at Kala-Kala, Peru. Other populations are maintained on research stations where they have become semi-domesticated and are being closely studied. (Plates 2 and 5)

The vicuña is the smallest species; it is a slim and graceful and agile animal. The wool is very short, 2 to 3 cm in length, and is of a yellowish colour. The average yield of the short, fine fibre is only 150 g per year. The layering of fibres is very similar to
that of the guanaco. The fine internal fibres are a brownish yellow colour and the external or coarser superficial fibres are red brick shade.

The vicuña has the unique characteristic of a large hank of fibre which grows only on the chest. The fibres are longer and stronger than those of the rest of the body, and the colour is light yellow to white.

Vicuñas have always been prized for their wool and hide. The Incas wove fine garments such as ponchos and shawls from the fibre. They were worn only by the nobility. In recent times clothing made from vicuña wool has commanded very high prices. With adequate protection and a programme of planned regeneration, the vicuña stocks could again become highly productive. Economic prospects are bright. The vicuña is the symbol of the animal production of Peru, and it may in the future provide an animal industry of great economic importance for the people of the high Andes.

**Llama**

This is the domesticated species. Like the alpaca it inhabits the Altiplano regions of Bolivia and Peru. There are, however, small populations in the north of Chile, Argentina and Equador. Generally they graze on the sides of mountains and eat the medium to long grasses of the Altiplano. (Plate 3)

Llamas are tall, robust animals which reach a height of 1.10 metres and weigh up to 100 kg. They have a carcass weight of 54 kg. It is possible to shear 2 kg of wool a year. Most of the meat from the llama is consumed by the people of the Altiplano. Small quantities are exported to the coast and the jungle in the form of processed meats. The leather is suitable for making shoes, sandals and bags. The fibre is long and coarse with a variety of colours, blacks, browns and whites. Quite often these colours are mixed on the one animal. The wool is used for making twine,
bags or sacks, blankets and even clothing. However, because of the robust constitution of the llama they have been bred mainly as beasts of burden for the transportation of goods, and this is their principal function. They are normally seen in caravans. They have a great resistance to harsh environmental conditions and a notable endurance for distance with loads weighing up to 40 - 50 kg. They carry loads over rough terrain to otherwise inaccessible parts of the Altiplano where vehicles could never reach. They are used for religious sacrifices; pure white animals being preferred for this purpose. The llama is the symbol of animal production in Bolivia.

Alpaca

The description of the alpaca requires a great deal more explanation. The domestication of this species made it of great economic importance. There is a considerable literature. (Plates 4 and 5)

Breeds

It is believed that even before the appearance of man in South America there were already two distinct breeds of alpaca, the Huacaya and the Suri.

Fibre characteristics

The Huacaya fibre is rough in appearance and has a well-defined crimp in the wool rather like the wool on a sheep. The Suri fibre is lustrous and smooth and has no crimp formation. The Huacaya fibre readily accepts coloured dyes. The Suri will not absorb dyes with the same ease and it is necessary to mix these fibres with others in the textile-making process. Huacaya fibre is more sought after than the Suri.
Adaptation to the environment

The Huacaya has more resistance to the stresses of the environment than the Suri, which has the higher mortality rate among both adults and the young. They prefer a kinder climate.

Appearance

The Huacaya breed is more robust and stronger in appearance than the Suri. The differences between the two phenotypes are seen in the different disposition of fibres or wool. In the Huacaya the wool grows perpendicular to the body and forms compact staples which are almost square in cross section. In the Suri the fibres grow parallel to the skin forming lank round staples that cover each side of the body leaving a line down the middle of the back.

The alpaca, like the other camelids of South America, is the source of meat, wool, skin, milk and manure. The most important of these, economically speaking, are wool, meat and skins.

Meat production

a. Body weight

The young alpaca has a very fast growth rate. Bustinza and Gallegos (1970) observed that alpacas with a weight at birth of 9 kg weighed 29 kg when weaned at 8 to 9 months of age, with slight variations for sex and breed.

Growth rate continues to three years of age when the average weight is 54 kg. The rate slows to six years of age, average weight is 65 kg. From 6 years of age onwards there are small increases in liveweight. Fernandez Baca (1971) reported a top liveweight of 70.5 kg for the
Suri breed and 69.8 kg for the Huacaya. Barreda et al. (1975) reported maximum weights of up to 72 kg in males.

Significant weight differences for sex and breed have not been established although it would appear that males weigh more.

It has been established that the age of the mother affects the weaning weight of the young alpaca. Mothers of two years of age had an offspring of an average weight of 25.5 kg at weaning. For each year of mother's age up to 7 years there was a significant increase in the weaning weight of offspring. Weaning weights of 28.2 kg were recorded from mothers of 7 years of age. After this age the effect of the mother has less significance for the weaning weight of the young animal.

b. Yield of meat

Generally speaking the meat yield of the alpaca is high, with no great variation for age or sex. Ccopia et al. (1974) showed that at two years of age, when most alpacas are sold, the carcass weight is about 20 kg. This increases up to 4 years of age when it reaches 29 kg. At 5 and 6 years of age the carcass weights are 29.3 kg and 28.3 kg respectively.

Roman et al. (1973) and Calderón and Fernández Baca (1972) quote figures of 55 percent with maximum figures from Ccopia et al. (1974) reaching 59 percent. Many observations have shown clearly that higher yields can be obtained from males than from females or from castrates. The figures indicate that alpacas, even when they have not been selected for meat production, have a higher carcass yield than either sheep or cattle. Tellez (1965) found sheep and cattle to have dressing percentages of 50 and 47 percent respectively.
c. Quality

Studies by Belon and Clavo (1968) and more recently by Paredes and Bustinza (1978) indicate that alpaca meat is high in protein and low in fat content. The quantity of protein in alpaca meat does not vary with breed, sex or management. Protein percentage is 20.3. Alpaca meat has approximately the same protein content as that of other domestic animals. The proportion of water is not significantly influenced by sex, breed, age or origin, although it seems that young animals and females have slightly more water in their meat than males. The average percentage of water in alpaca meat is 75.8. Mertz (1971) quotes the percentage of water in the meat of other animals as between 73 and 76 percent.

Alpaca meat has a much lower fat content than other red meats. The quantity of fat is not influenced by the above mentioned factors, and the average being 1.33 percent.

Alpaca meat contains 1.09 percent ash with a minimum of variation between age, breed and sex (Morrison, 1969). This is similar to other meats.

Fibre production

The wool or fibre of the alpaca is a product of unequalled quality and has special properties which are greatly appreciated by world markets.

a. Wool weight

Bustinza and Gallegos (1970), Bustinza, Bravo and Chaguilla (1977), and Gallegos and Avila (1979) have investigated alpaca wool production with similar results. Fibre production is influenced by breed and sex, and is affected by age. The first shearing is at nine months of age with an average yield of 1.15 kg per head. Weight
of wool yield increases with age (1.61 kg at two years of age; 1.87 kg at three years of age; 2 kg at four years of age). Small increases can be expected to five and six years of age with average yields of 2.11 kg and 2.17 kg respectively. After six years of age production decreases to two kg.

The Huacaya breed has the superior production of wool and the male tends to produce slightly more than the female.

Wool production is influenced greatly by age of the mother at birth of the offspring. Wool weight of the offspring, in the first year, increases in direct proportion with the age of the mother, until the mother's age reaches six to seven years after which the wool weight effect seems to decrease. This is to say that offspring from mothers at six to seven years of age give the greatest wool weight, which would indicate that the maximum age for maintaining a female in the herd would be seven years of age. Past this age the production of the animal itself tends to drop and has a negative influence over the production of the offspring.

b. Staple length

Length of staple varies according to age and breed. It is the latter however that has the greater effect as shown by Flores and Gallegos (1979). The fibre from the Suri breed has an average length of 15.5 cm while that of the Huacaya is only 11.5 cm. The Huacaya fibres on the surface are rough and cramped and form a compact staple, while the fibres of the Suri are smooth, lank and straight forming a lengthy staple that lacks compaction or density.

The younger the animal the longer the staple length. Flores and Gallegos (1979) have figures which show that alpacas, shorn at one year of age, had a staple length
of 16.5 cm whereas at six years of age the average was down to 12 cm. This can be attributed to the fact that the follicles are functioning at their maximum in the first year.

Males produce staples of slightly longer length. Carpio and Martin (1969) found that in 265 days the staple grows an average of 8.93 cm. Therefore it can be affirmed that staple length of wool grown for one year can attain dimensions that satisfy the demand of the textile industry (7.6 cm). However, 85 percent of wools that have grown for only 265 days are suitable for the combing process and 15 percent for the carding process.

c. Fibre length

The length of fibre with wools of eighteen months growth, varied between 15 and 19 cm in the Huacaya breed while in the Suri the length ranged between 17 to 20 cm (Villarroel, 1963). In both cases there is present a large variation. This length of fibre growth in 18 months seems to be what one would expect to see after one year growth (Flores and Gallegos, 1979).

Recent studies carried out by Bustinza (1979) suggest that the length of fibre is effected greatly by age, however, the effect of sex and breed are small. Therefore in the Huacaya breed the length of fibre varies from 12.3 to 16.38 cm in females, and from 13.10 to 16.9 cm in males. The fibre of the Suri female varies in length from 13.15 to 17.11 cm and in the males from 12.97 to 16.98 cm. The best length in both cases corresponds to one year old animals and the lowest figures correspond to animals over six years of age, i.e. length decreases with age of the animal.

On the other hand Carpio and Martin (1969) show that the length of fibre after 265 days in the Huacaya averages 9.6 cm, with a range of 6.0 cm to 13.9 cm. These figures demonstrate that length of fibre of the alpaca
is sufficient in all cases to meet the requirements of the textile industry; the basic requirement being 7.6 cm for the combing process.

d. Fineness

Villarroel (1963) and Carpio and Arana (1975) have demonstrated that in the skin of the animal, the diameter of the fibre increases from above to below and from front to back. The finest fibres are on the top line of the animal while the coarser fibres are in the lower parts like the thigh. The areas with the finest fibres are the croup and withers (20 microns) and the areas of coarse fibres are around the thigh and flank (40 microns).

The mid-rib area of the body of the alpaca has the average fibre diameter for the animal. There is no difference between either side of the body. Villarroel (1963) concluded that no difference exists between the fibre diameter of the Suri and the Huacaya, but there is a large difference of fineness in various herds and within breeds. On a visual basis, it seems that the wool of the Huacaya is slightly coarser.

Villarroel (1963) in studying fineness and length of fibre at 18 months of growth found that fibres of smaller diameter are generally uniform while fibres of large diameter present the greatest variation. On the other hand the variability of diameter and length is influenced by crimp. Fibres with a regular crimp are more uniform while fibres with little or no crimp have a large variation that changes drastically. This variation to a large extent is determined by the quality of pasture on the Altiplano.

Age also significantly affects the diameter of the fibre. Flores and Gallegos (1979) found with fibres starting from 18 months of growth that the diameter measurements became coarser with age. Therefore the
fibre of animals of one year of age had a micron reading of 17.4 microns while fibres from six year old animals had readings of 27.5 microns. It would seem that the older the animal the coarser the fibre becomes, although this process is slow.

e. Fibre follicles

Histological studies of the skin of the alpaca have disclosed that the structure, number and disposition of the follicles for the Suri and Huacaya breeds are similar to those of the other species. A group of follicles is typically made up of primary follicles with a variable number of secondary follicles (2 - 17). They are separated by connective tissue. Tapia (1969); Gayton (1967); Tapia, Bustinza and Matusita (1975) have described the follicle structure as follows: "The primary follicles are of a large diameter and have sebaceous glands, sudoriferous glands and an arrector muscle. They are not completely surrounded by secondary follicles. The secondaries are normally localized to one side or the other. The secondary follicle is smaller in diameter and may have a sebaceous gland but there is no arrector muscle or sudoriferous gland. There are normally groups of 2 to 17 secondary follicles surrounding the primary follicles. The fusion of secondary follicles in the superficial layer of the skin forms a unique radial sheath."

Normally for each group of follicles there is only one primary. The average secondary to primary follicle ratio is similar for both breeds and is normally 5.5. The density of follicles in the skin of the alpaca has been determined at about 17 follicles per square millimeter.
THE FUTURE FOR CAMELID PRODUCTION

Peru and Bolivia possess approximately 90 percent of all South American camelids; Peru has 70 percent of the world population, mainly alpacas, vicuñas and a great many llamas.

The populations of vicuñas may well have increased by 150 percent, and by 20 percent for the domestic species. It should be stated that Chile has a large number of guanacos. (Table 1)

About 30 percent of the domestic species are owned by large cooperatives (Empresas) and the remaining 70 percent belong to small property owners who live in the high alpine pastures of the Andes.

These populations emphasize the great economic importance of the camelids for the prosperity and development of the countries in which they exist.

In general, the meat of the domestic camelids is used either fresh or dehydrated. The blood is used in sausages and other processed foods. The intestines and organs are similarly utilized. The tallow is used to make candles. Bones are made into meal and are also used as pet food and in the making of tools. The foetuses are eaten and have a role in mystic and religious practices. The dung is dried and used as fuel, providing a valuable source of energy for cooking in areas where trees do not exist. It is also used as fertilizer.

The fibre, especially that of the alpaca, is of primary importance. In Peru 90 percent of it is exported and the rest is used internally for weaving ponchos and other clothing, blankets, sacking, rope, etc.

The llama is and will continue to be an important pack animal in areas where vehicles cannot be used and there is no other means of transportation.
Fernández Baca (1975) suggests that approximately 200,000 families live directly from the exploitation of camelids. Flores (1975) suggests that this figure could be doubled if one includes the small commercial intermediaries such as tanners, skin buyers and many other people who process or work indirectly with the products of the alpaca and llama. Economic prospects for the future in the commercialization of products from the South American camelid are good, although many problems remain to be solved.

The economic potential of the South American camelids is exemplified by production and population figures in Peru. In 1979 there were approximately 3,091,140 alpacas. Some 10 percent of these produce 8,650,000 kg of meat per year with a value of about US $10,380,000. Shearing produces 4,500,000 kg of wool with an annual value of US $47,250,000. This gives a total of some US $57,630,000 per year. If the population of the llama in Peru is about 1,500,000 it would be possible to kill 150,000 head per year yielding approximately 6,000,000 kg of meat with a value of US $7,346,938. The wool yield would be 900,000 kg annually, valued at US $4,200,000. This then would give a total amount of US $11,546,438 from llama products alone. Production from the vicuña, especially the skins, which can fetch US $1,000 each on the world market, could realize US $6,000,000 per year. Given the total population of the three species of camelids in Peru and their production a grand total of US $75,476,938 could be realized per year (Table 2). These figures do not take into consideration the very valuable skins of young alpacas and llamas.

Similar economic possibilities could be realised in Bolivia where there are the three species: vicuña, alpaca and llama; and in Chile and Argentina where the camelid population is mainly guanaco.

The populations quoted could be doubled, or perhaps tripled if the investment and interest were increased.
Limitations

The following are some of the limitations to the raising of domestic camelids, and to the management and utilization of the wild species.

1. Low fertility, high embryonic mortality and deaths of calves soon after birth are all problems that are specific to the alpaca, the species that is exploited most.

2. Poor nutrition is a major problem throughout the year as native pastures lack the nutrients necessary for animal health and production. Wool, meat and milk production are adversely effected. Nutrition has a major bearing on fertility and mortality. Much experimental work is being done and there is a possibility of the introduction of high producing exotic pasture plants into the Altiplano. Already the experimental stations at La Raya (4300 m above sea level) are establishing pastures of rye grass, white clover and alfalfa. These pastures are being grazed experimentally by alpaca and vicuña. In the Altiplano of Peru these same types of pastures are being introduced rapidly mainly for sheep and cattle production; there would appear to be no reason why alpaca could not be grazed on such improved pastures, if not throughout the year, then at least during those times of the year when mating, birth and weaning are taking place.

3. Other grave problems facing the adult domestic species of camelid and, to a lesser extent the wild species also, include the ectoparasite itchmite (*Psorobla ovis*) which cause the condition known as sarna; and an acute diarrhoeal disease which is common in young animals and has serious implications. The treatment of both conditions is unsatisfactory as no therapeutic agents providing specific control have yet been found.

4. Another problem, especially with alpacas, is that
genetic improvement programmes for the selection and use of superior producing animals are lacking.

5. The major problems which must be tackled in the near future include the commercialization of camelid wool and meat. At the present time procedures are cumbersome, inefficient and wasteful, employing many intermediaries to the detriment of the producer. A radical reorganization in handling and marketing is urgently required in order to improve the economic situation of those who raise the llama and alpaca. Recent programmes of management and rational utilization of the wild species (guanaco and vicuña) have begun in Chile and Argentina, and although Peru has taken steps in this direction in recent years there still remains a great need to design joint marketing programmes on an international basis, especially for wool, in order to eliminate unscrupulous commercialization and contraband consignments.

All these factors are impeding the production and economic realization of the industry. The problems are not insoluble. Some required activities are:

a. Research programmes to investigate the social, cultural and economic situation of the peasants who raise alpaca and llama, and who would benefit from the introduction of the vicuña.

b. Improved pastures should be greatly extended and further research initiated in order to find solutions to problems of malnutrition and reproduction of the alpaca.

c. Disease control measures are vitally necessary, together with investigation of all the pathological conditions occurring in camelids which are of economic or public health importance.
d. Rational breeding programmes must be initiated and a start can be made by screening camelid populations for high producing animals for breeding purposes.

e. The problem is not only one of increasing the output of wool; there is also a major difficulty in commercializing these products. The manufacture of alpaca and llama wool fabrics should be undertaken in the countries where the wool is produced. The production and marketing of meat call for improvement to present a high quality product efficiently produced under hygienic conditions.

It is considered that these actions would lead to a doubling of the economic returns from South American camelids, thus increasing the wealth and well being both of the region and of the individual countries.

Table 1: Estimated population and distribution of South American camelids

<table>
<thead>
<tr>
<th>Species</th>
<th>Peru</th>
<th>Bolivia</th>
<th>Chile</th>
<th>Argentina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpaca</td>
<td>2 887 400</td>
<td>300 000</td>
<td>20 000</td>
<td>Few</td>
</tr>
<tr>
<td>Llama</td>
<td>915 000</td>
<td>2 500 000</td>
<td>70 000</td>
<td>500 000</td>
</tr>
<tr>
<td>Vicuna</td>
<td>30 000</td>
<td>2 000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Guanaco</td>
<td>Very few</td>
<td>Very few</td>
<td>?</td>
<td>100 000</td>
</tr>
</tbody>
</table>

Source: Fernandez Baca (1975)
Table 2: Estimation of yearly economic potential of the South American camelidae

<table>
<thead>
<tr>
<th>Animal</th>
<th>Meat</th>
<th>Wool</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpaca</td>
<td>8,500,000</td>
<td>4,500,000</td>
<td>US$ 10,380,000</td>
</tr>
<tr>
<td></td>
<td>4,500,000</td>
<td></td>
<td>US$ 11,910,000</td>
</tr>
<tr>
<td>Llama</td>
<td>6,000,000</td>
<td>1,200,000</td>
<td>US$ 7,346,938</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>US$ 18,750,738</td>
</tr>
<tr>
<td>Vicuna</td>
<td>300,000</td>
<td>10,000</td>
<td>US$ 360,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>US$ 6,360,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>US$ 75,476,938</td>
</tr>
</tbody>
</table>

Figure 1: Body weight of alpaca at various stages

Figure 2: Body weight of offspring in relation to age of dam
Figure 3: Carcass weights of alpaca at various stages

Figure 4: Alpaca's carcass yield at various stages

Figure 5: Wool weight of alpaca in relation to age

Figure 6: Wool weight of alpaca offspring at one year of age in relation to the age of mother

Figure 7: Variation of average diameter (in microns) along the length of staple in the Huyacaya breed aged 18 months

Figure 8: Diameter of alpaca's fibre at various age
Plate 1: Guanaco

Plate 2: Vicuña

Plate 3: Llamas.
REFERENCES AND BIBLIOGRAPHY


Belon, J. y N. Clavo. 1968. Análisis bromatológico de las carnes de alpaca (Lama pacos) y llama (Lama glama) que se consume en la ciudad de Puno. Tesis Médico Veterinario Zootecnista. Universidad de Puno, Peru.


Bustinza, V. 1977 La Selección y el uso de los registros en la Alpagueñía. I Conversatorio Multi-sectorial sobre Desarrollo de Camélidos Sudamericanos - Alpaca, Peru. Puno, Peru.


1979 Producción de carne y de fibra de la Alpaca. 3ra Convención Internacional sobre Camélidos Sudamericanos. Viedma, Argen- tina (In press)


1979 Producción de vicuñas de Kala-Kala. 3ra Convención Internacional sobre Camélidos Sudamericanos. Viedma, Río Negro, Argentina (In press).

1979 Población estimada y Producción de vicuñas del Peru. Conferencia en el Instituto Americano de Arte de Puno. Puno, Peru.

Gabbrera, A. 1931 Sobre los Camélidos fósiles y actuales de la América Austral. Universidad Nacional La Plata, Argentina.


Moro, M. y C. Guerrero. 1971. La Alpaca; enfermedades infecciosas y parasitarias. Ministerio de Agricultura, Universidad Nacional Mayor de San Marcos e IVITA. Boletín de Divulgación, No. 8. 64 p.


Sumar, J. 1976 Avances en la Investigación de Camélidos Sudamericanos. La Paz, Bolivia (suetos).


DROMEDARY PASTORALISM IN AFRICA AND ARABIA

G. Dahl and A. Hjort

Summary

The restrictions inherent in camel-based pastoralism are discussed. They include the seasonality of production and the labour requirements involved. Camels are considered both for direct production of staple food and as a means of obtaining political control.

Introduction

The purpose of the present paper is to give an overview of different economic systems where the breeding and ownership of camels play a significant role, and to indicate some of the strengths and weaknesses of such systems. The emphasis is on camel pastoralism in Africa and Arabia. "Camel" here refers to the dromedary. We will deal with the use of camels as draught and transport animals only indirectly as creating an outlet for camels from "family herds" kept by pastoralists.

While there are a number of anthropological efforts toward more general studies of cattle pastoralism, there have been few efforts made within the equivalent field of camel pastoralism. One exception is Rubel (1969) who has tried to create a "generative model" for residential and kinship patterns, comparing a number of pastoral societies with varying emphasis on camels or small livestock. Her hypothesis is that small stock pastoralism necessitates a wider range of pasture and water than camel pastoralism, and that the strict ideal of patrilinearity has to be compromised in practice, so that social organization allows the small stock herder to maintain a widespread network of alliances also outside his patrikin, ensuring access to such resources. Rubel has been criticized (Pastner, 1971) for using
untrustworthy data and for relying too heavily on simplistic assumptions on the hardiness of camels. One of her critics, Lewis (1975; 1977), however, notes the correlation between cultural differences and variations in "species emphasis" among neighbouring pastoral peoples in Northern Kenya and suggests that different combinations of livestock could indeed provide a generative model for predicting forms of social organization.

The focus is on systems of production rather than on particular groups of people or their cultural traits. The concern is both with constraints which may be caused by ecology and an economic dependence on camel herds, and with restrictions on production caused by the social organization.

Reproduction and risk

Perhaps the first trait of camel keeping that we have to consider is that it is fundamentally a high-risk undertaking (Sweet, 1965; Stauffer quoted by Bulliet, 1975) due to the very slow reproduction rate. Only when she is about six years old does the camel dam start to bear calves, and then normally only one calf every second year. This can be contrasted with the cow, who gives her first calf about 3 or 4 years old and then one every following year. If a camel owner is struck by misfortune and left only with a minimal number of camels or none at all, rebuilding the herd is a very slow process. Breeding animals are very expensive to buy, and owners are often reluctant to part with them. Losses of camels are in many cases final, and just as definite as when a farmer or peasant becomes landless. A dramatic example is the fate of the Sakuye Borana in Northern Kenya who lost virtually all their camels in a war over ten years ago. Practically all the Sakuye were pushed out of their traditional livelihood, being unable to provide proper care for the remaining animals and incapable of expanding their holdings fast enough to re-enter viable
pastoralism. They were forced to leave their area in order to seek other incomes and thereby lost effective control over their pastures, which are now used by other camel herders. It is now almost impossible even for rich Sakuye to purchase breeding animals in the market (Dahl and Hjort, 1979).

The hazards of camel reproduction have also been used as an explanatory variable by authors (notably Sweet, 1965) who have sought to understand the institutionalization of raiding in Arabian camel-owning societies. By acquiring animals in a raid, the herd owner can preclude several unproductive years in the development of his herd. One partial solution to the risk is that many camel-owning societies in Africa and Arabia have systems of property holding, which redistribute the risks between herd owners. All the animals of a particular patrilineal kinship group are in some sense regarded as common property and are marked with one single brand. Each individual herdowner, however, can dispose of his stock as he pleases, as long as he fulfills his duties to take part in lineage redistribution of stock to those stricken by misfortune. Such redistributions may be organized by a council consisting of all mature herdowners in the lineage, or by specially appointed elders or tribal chiefs (Dahl, 1979). Among the Sakuye, the lineage members were responsible for helping each other to retrieve stock that had been lost, and to make a collection of a nucleus herd for any member who had lost his camels through misfortune: on condition, however, that he was not known to have spent capital (female breeding stock) carelessly—for example by selling it. (Due to the high risks associated with herd regeneration, the camel husbandman must show respect to capital expenditure: the cultural system often stresses this by various semi-ritual taboos against sales.) When a majority of the camels of the Sakuye people had been lost, such counter-measures as lineage redistribution were of course ineffective.

Forms of lineage redistribution may be supple-
mented with systems of mutual loans of camels, so that in practice the herd which is managed by one household belongs to many owners. Such a system of chains of loans has been described by Spencer for Sakuye's neighbours, the Rendille (Spencer, 1973).

Management and labour

It is not only the pattern of herd reproduction which is significantly different for camels and cattle. Camels are able to move quickly and to reach distant pastures. Such movements are necessary to achieve a varied diet. In comparison with cattle, camels require frequent "salt cures" at licks or on pasture on salty soils, unless there is access to water with appropriate mineral content. Another reason for mobility is the need to avoid hygienic problems and tick infestation. Camel calves are very vulnerable to ticks, and as a counter-measure the pastoral camp should not remain more than ten days at the same place. Camel-oriented societies differ in the degree that the main body of household members follows the camel herd in all its moves: but when they do, much energy has to be spent on the frequent erection and dismounting of tents. Camp moves are usually more frequent than among cattle herders.

Neither mating nor birth can be left to the camels themselves.: the attention of experienced herdsmen is necessary. Camels, especially dams about to calve, have a tendency to stray and tracing them involves much work.

Although camels frequently go for long periods without water, they drink a great deal whenever they can. In the dry seasons it can be quite a task to draw 90 litres of water per animal from a deep well. Watering at pans, which is easy with cattle, requires great attention with camels especially at places where livestock of other species are watered as well. Camels tend to get into the water and foul it and animals of other species refuse to take it.
Camel pastoralism can generally be said to be more troublesome and demanding than cattle pastoralism, though there are seasonal changes to the pattern. Two slightly different examples can be mentioned, from southern Arabia and Kenya.

Among the Al-Murrah of Rub-al-Khali, the members of a particular patrilineal group tend to congregate around its oasis or permanent well during the hot season. There is not much herding to be done as the vegetation is restricted to narrow and isolated patches and the camels do not stray far from the watering places. By contrast, the cool season is a period when much time has to be spent in aiding mating and calving and in tracing camels which wander (Cole, 1975). It is a time of plenty of milk and easy access to water and pastures. Families gather together and meet other patrilineal groups. There is much inter-clan feasting.

In northern Kenya, the rainy season similarly involves both work linked to camel reproduction, and congregation and enjoyment. Since resources are abundant, but also because of a narrowing down of the areas open to camels, herds and people are concentrated to areas with good drainage. Families which during the dry season tend to be parcelled out into many small sub-units are in the rainy season able to stay together. As drought proceeds, the main camps have to live closer to the permanent waters, but the camel herds and their herdsmen roam widely in search of pasture. "Almost every able-bodied person, including children from the age of seven, is pressed into service..." (Torry, 1978). Wet season routines sometimes demand a very intensive input of labour by a restricted number of people. Dry season routines, on the other hand, put a strain on the number of people available for there is a proliferation of tasks.

One way of countering the high risk of camel pastoralism is to combine camel rearing with the rearing of sheep and goats which reproduce quickly, and so can
provide a viable pastoralism in the case of misfortune. This implies also serious constraints on man-power. For example Torry (1977) indicates that for the Gabbra in northern Kenya, the labour intensive nature of multi-species stock management denies able-bodied persons considerable freedom from productive work by periods especially as compared with cattle pastoralists. The Gabbra normally keep different kinds of stock in their household property and most Gabbra households are dependent on immigrant labour at critical seasons. Gabbra households in a camp also try to pool labour resources to cater for the family herds through such periods.

Weighing the disadvantages of one animal species against the advantages of another means that the minimal number of herdsmen must be large in order to provide specialized care to each species.

A family which owns only camels, has to give special attention to the several categories of camels. Among the Sakuye, for example, it is said that herd-owners tried to mate all their dams with the same male and then to separate this group from contact with other males until it could be seen, after one to four months, whether the dams were pregnant or not, lest other rutting males would cause miscarriages or injure the dams. The dams and their sire would be sent away, while the newborn calves and their mothers, which constituted another group demanding special attention, were kept close to the camp. This group was put under a rule of ritual seclusion and could only be herded and milked by chaste young herd boys. Among the Al-Murrah, Cole (1975) found that there was particular concern over a similar category of newborn camel calves and their mothers, which had to be given water every week, and that these were kept separate from both the mobile milch camels and the pregnant dams which were left unattended close to the camp.
Subsistence production

In spite of the fact that there are many monographs on groups concerned with camel herding, detailed production data are scanty. The main food product obtained from a camel herd is milk. The camel is in many ways a more reliable source of milk than the cow. She produces milk in greater quantity— to mention one example, a Sakuye camel dam in northern Kenya can be expected to give about 4 kg daily as compared to 0.5 – 1.5 for a cow in the same area. At the peak of lactation, the daily yield can be as much as 12 kg. Knoess (1976) found average daily milk yields of between 2 and 8.4 kg in Afar camels in Ethiopia. The lactation period may last for 18 months: up to a year is considered normal under traditional pastoral management. This means that the owner of a number of camels can have safe access to milk throughout the year.

In areas with only one rainy season, a majority of the camels are sometimes at the end of their lactation just before the onset of the rains, and the end of the dry season may involve a critical period of food shortage for the pastoralist if he has not access to grain or other products which are foreign to camel rearing. It is interesting to note, that the main area where there are almost totally subsistence-oriented camel pastoralists is in northern Kenya, which has an expected pattern of two rains per year. There, sections of the Rendille and Gabbra live almost exclusively based on the products of their camels and small stock.

There are, however, some impediments to milk production even in that region. If one or two consecutive rains fail, there may be a delay in camel reproduction — and hence lactation — which is more serious than in cattle rearing or small stock pastoralism. A camel may go one or even two years without beginning a new lactation. There is a risk that all the camels go in milk simultaneously, which gives one year of abundance at the cost of the next year's milk supply.
Milk goats, and sheep for slaughter, ensure a more reliable supply of food. Goats come into milk quickly after the onset of rains. This is one of the reasons why camel rearing is frequently combined with the husbandry of small stock.

Subsistence pastoralists rarely slaughter camels for meat. Only on ritual occasions or when there are large gatherings does such slaughter take place, and when the camel is old or weak. That this is so, depends upon the value of females for reproduction and of males for a wide range of alternative uses. To slaughter a camel is a major decision, but the gap after a slaughtered goat or sheep is quickly filled: the meat of the smaller animal can also easily be consumed by the family without involving any larger group in communal sharing.

In northern Kenya, camels are occasionally bled to provide for particular human demands of iron, salt and other nutrients. The use of camel blood as human food seems to be restricted to those Nilotic peoples who have acquired camels (notably the Turkana), to camel-owning Boran groups and to the most western Somali. It is not acceptable to orthodox Islam.

Apart from the production of milk, meat and blood, camels supply skins and, theoretically at least, wool. Knoess (1976) who suggests that Afar pastoralists be made to sell camel wool, notes that its use is unknown in Ethiopia, and the same goes for the rest of the Horn of Africa. Skins are used by pastoralists for household utensils, whips and sandals are sometimes exported.

Marketing

The only area in the world where camel pastoralism seems to be predominantly subsistence-oriented is northern Kenya. Even there, camel pastoralists rely to some extent on neighbours practising hunting or alternate forms of pastoralism. Most other camel pastoralists depend on
exchanging some form of goods or services with their neighbours in order to obtain supplementary foodstuffs from them. In such societies camel milk continues to be an important food, but the diet is not exclusively built on it. Camel milk does not have good storing qualities; in fact, there is no consensus in the literature as to whether it can be churned or curdled (Dahl and Hjort, 1976). Although it has a pleasant taste, it is not always acceptable to the consumer, and it has little or no market outside the community of camel herders or ex-camel people.

It is difficult to ascertain the extent to which camel pastoralists in Africa and Arabia have traditionally been oriented towards a meat market. Due to the long intervals between camel births, it is difficult to perceive of any camel production as primarily meant to supply meat for the market. Bulliet (1975) mentions brisk markets for camel meat in Libya and Morocco, and in the nineteen sixties, when Asad made his study of the Kababish of Sudan, the latter were, despite serious legal restrictions, engaged in the export of camels to the Egyptian beef market (Asad, 1970).

In 1970, Ibrahim and Cole (1978) noted that hardly any camels were sold by the Al-Murrah Bedouin, the camel meat in urban markets coming from aged animals, while a majority of those they came into contact with in 1978 had been involved in such sales.

In northern Kenya, prices have risen considerably both for male and female camels during the last decade, a fact which is usually explained by increased Saudi Arabian demand. Swift (1979) also reports a recent increase in the Somali camel export, not least to Saudi Arabia. However, it is not altogether clear that this is due to an increased demand for camel meat. Cole (1975) states that although camel meat is no longer as popular as it once was, there is now a great demand for pure-bred milk and riding camels among the Saudi Arabian elite and markets are expanding. Schmidt-Nielsen (quoted
by Bulliet, 1975) suggests that the camel offers a most obvious solution to increased meat production in arid zones with a low natural vegetation density that cannot easily be increased. However, despite the camel's superior adaptation to arid climates, the risks are great, the meat offtake fairly low and labour costs high. In the case of Somalia, a recent report indicates an annual offtake of 5 percent including both domestic meat consumption and export (USAID, 1979).

Any demand for slaughter camels has so far had to compete with the demand for transport animals.

The fact that the caravan camel has had great historical significance for north Africa, the Middle-East and the Near East is well recognized. It was accentuated recently by Bulliet (1975) in a volume which presents an original discussion of how the domestication of the camel and the invention of the camel saddle 2 100 - 2 500 years ago brought a revolutionary change to transportation techniques and hence transformed the economic political and social history of the near East. Transportation became less costly by camel caravans than by the wagons which had been used before, and militant camel nomads offered their protection and took over the trade.

Today, in the context of long-distance trade, the camel as a pack animal has been replaced by motorized transport, but its use as a work animal is still significant among many Arabian and Saharan people, who do not necessarily themselves breed camels. The use of camels for ploughing is common in many farming communities, for example by Bedouin cultivators in North Africa and by farmers in Yemen. Access to good transport animals is also crucial to people who pursue other forms of pastoral nomadism than that built upon camel rearing. For example, in Isiolo District in Kenya, there used to be two groups of Boran pastoralists: one specialized in camel-rearing and the other in cattle-rearing. Until the camel economy broke down in the nineteen sixties (due to a secessionist war in northern Kenya) the cattle-owning families used
to have two or three camels each for transport purposes. This facilitated movements between different camp sites when pasture conditions necessitated such moves. Scarcity of transport animals has now slowed down their pastoral movements to the detriment of the proper care of cattle and small stock. Their transport camels formerly enabled them to camp at a distance from the rivers and wells, which was advantageous both for human and animal health reasons and for the protection of pastures close to permanent waters. The camels could transport domestic water to the human household, or water and grass to animals which had to remain in the camp, i.e. young or sick animals, or to transport weak small stock or calves form one place to the other. Within the camel economy itself there was of course also quite a demand for transport camels, reducing the proportion that could be exported.

Camels need close attention and constant movement if they are to reproduce well. The area where camels can reproduce is usually more restricted than where they can be put into work, and hence one will find transport and work camels more scattered than camel dams. The literature on camel economies frequently does not recognize this, and many sources state numbers of animals owned in terms of a sexually neutral category, which makes it difficult to judge the nature of the camel's economic role in the society concerned.

The number of people actually specializing in camel pastoralism is not very large, but the number of people who actually depend on carrier camels may be considerably larger. It may even be that it is in relatively short-distance transports for small pastoral producers and farmers that the camel had its most important role rather than in the context of the caravan. There appears to be a general opinion among writers on camels, that the demand for transport animals is decreasing, an opinion based on the observation of the changes in the structure of long distance trade. More research is needed into such trends, and to ascertain if there are also changes in the demand for short distance transport animals.
Predatory pastoralism

Having discussed the capacity of the camel for subsistence and commercial production we should also consider a third historically important aspect, which follows from the extreme mobility of the camel, namely its political role. The areas where we find camel pastoralists today are areas in the periphery of central states: areas where scarce resources make it uneconomical to try and maintain strict political control over people who tend to evade such control. Pastoralists can often react to political pressure by retreating into inaccessible regions. They are difficult to rule, and historically have enjoyed military advantages through the agility of their animals.

There is a specific pattern of predatory camel pastoralism (Bourgeot, 1975) which is neither primarily subsistence-oriented nor utilizes the camel as a means of direct production of marketable goods.

The Tuareg (Tabashek) provide a good example of this. In traditional Tuareg society, camel ownership tended to be restricted to a hereditary caste of noblemen, whose herds were tended by slaves. These slaves were of separate ethnic origin (negroid), like the sharecropping vassals using land owned by the noblemen. Commoner Tuareg specialized in religious services, in goat rearing or oasis cultivation and paid tribute in kind to the camel owners in return for protection. Bernus (1975) describes how, under the colonial pax, this service offered by the camel-owning noblemen lost its meaning and had eroded, giving rise no longer to castes based on qualitative criteria of types of wealth but instead to more clearcut quantitative inequalities. The Tuareg noblemen were typical of a system, in which camel-owning sections of diverse ethnic groups all over the Saharan area were able to maintain control over restricted patches of land of particular value - oases for cultivation, caravan centres, permanent well-fields and depressions with good grazing. Some of them, like the Daza of Borku (Johnson, 1969) maintained outright ownership over oases or palm trees but did not themselves cultivate,
leaving this to vassals or ex-slave groups, and returning only for the harvest. The Daza and their northern neighbours of Tibesti, the Teda, used to collect dates in early winter, and then use their nomadic camps as bases for caravans to other more sedentary people in order to exchange these goods for grain.

Systems of vassals and patrons are also found among the Bedouins of Libya and the Arabian desert area. In these areas, one can find dominant groups of noble, camel-owning Arabs who control land and are ascribed an elite status through reference to their places in tribal genealogies. In north Arabia, a system of ranked lineages is combined with a system of political control over vassal groups of small-stock shepherds, cultivators and hunters. This is exercised through control over pastures and wells along the trekking routes and over some oases (Sweet, 1965) from which the noblemen extract dates and wheat yearly, either by force or as shares from their proprietary holdings.

It appears likely that such systems will erode under the influence of modern commerce and the growth of a centralized state structure which favours members of groups which are more sedentary and living in closer contact with the state representatives. Cole (1975) notes a change in Saudi Arabia where now the most influential herd-owners are those with the largest sheep flocks, rather than those owning camels.

Political influence through "protection" diminishes in influence with the growth of the state - and predatory camel owners are possibly reduced to subsistence or commercial producers.

The future of camel pastoralism

The future of camel pastoralism seems to be at stake despite the wealth of technical knowledge and cultural accomplishments that it represents. The practical and political needs of camel nomads have long been neglected by national governments. Today there is a growing interest among planners
and researchers in the potential of the camel as a meat animal. That their efforts to develop the camel industry will benefit the pastoral camel people is to be hoped but is not self-evident. The different goals of development do not necessarily go together. In fact, it is usual with livestock development efforts in the arid zone that the local pastoral producers are only one of the "target groups" involved in the development objective. Their rights to social and economic welfare tends to play a more important role in rhetoric at the planning and fund-raising stage than in formulating actual policies, while concern for national interests and the pressures from politically influential urban consumers and traders may be more decisive.

It is illuminating to draw parallels to the cattle sector development in East Africa. A popular model for development is that of a stratified system whereby values produced in arid regions under traditional pastoralism are brought to commercial fattening ranches in areas with better grazing, e.g. in Kenya. Labour costs for the cow-calf operation are so high that it cannot be profitably pursued in the context of an enterprise relying on wage labour (Von Kaufmann, 1976). Fattening requires less labour and is the part of the production process which has the highest capacity for profit, whether undertaken by the commercial rancher or the traditional pastoralist. This form of integration of traditional production with modern beef industry gives little protection to the small primary producer but passes risks and costs on to him. Wealthy pastoralists who have the choice, keep their animals until fully grown. Poor stock-owners on the other hand may have to sell whatever stock they have, irrespective of age and at a low price in order to cover urgent needs. Only through the weakening of traditional systems and the impoverishment tends to start off a vicious circle of deteriorating husbandry practices, range degradation through decreased mobility, and lessened food production (Dahl and Hjort, 1979).

It is likely that the development of camel breeding will follow similar lines to that concerned with commer-
cialization of the cattle industry. As indicated above, camel reproduction under open range conditions is a difficult and labour-consuming process which may require intensive engagement of individual caretakers rather than cheap handling of camels en masse. A stratified system producing young animals for the beef market is also reminiscent of the common division between specialized camel breeding groups and the far larger population who use camels. A major difficulty with improving the camel industry so as to benefit the nomads is to safeguard institutional forms that can maintain control of the fattening process. It must be borne in mind that camel nomads have for centuries been producing for a market. What will be the economic and ecological consequences of a meat market that withdraws stock from the market for loaders and work animals?

Finally, there is no advocacy here of any attitude of paternalistic protectionism. That cultures are ancient or traditional is not alone a valid reason to maintain them unchanged, especially if the bearers of these cultures find a better way of life. But those who have the power to intervene in the systems of sustenance of others must remember to make a fair appreciation of the actual number of people employed and supported by the traditional system, and the availability of other similarly efficient sources of subsistence. There is indeed need for more research on camels, and it is important that such research should be geared to decreasing the risks to which pastoralists so far have been subject, rather than promoting commercialization as a goal in itself. Much harm has already been done to those who care for camels due to the failure to acknowledge that they have animals with specific needs, separate from those of cattle, and that special provisions have to be made for them when, for example, irrigation schemes and cattle development projects are planned. Modern science can also provide solutions to some of the disease problems that have hampered camel reproduction and health in the past and permit the camel economy to sustain and enlarge the population.
REFERENCES


Knoess, K.H. 1976 Assignment report on animal production in the Middle Awash Valley. Development of the Awash Valley, Phase IV, UNDP/FAO Project ETH/75/001


<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
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<tr>
<td>Stauffer, T.</td>
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<td>The dynamics of middle eastern nomadism - traditional pastoralism and Schulzian rationality.</td>
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THE TRANSPORT CAMEL OF THE RENDILLE OF MARSABIT DISTRICT, KENYA

H.J. Schwartz

Summary

The number of loading camels available per nomadic household is a major factor determining the choice of the seasonal pastures, the mobility of pastoral groups, and the maximum utilization of the productive potential of the nomadic herds. The Rendille are a camel-keeping, nomadic group in Marsabit District, Kenya.

Introduction

The Rendille are a pastoral people of Cushitic origin who inhabit an area of approximately 13,000 km² in the South-West quarter of Marsabit District, Northern Kenya. Most of this area is at a height above sea level of between 400 and 700 m and receives 200 to 600 mm rainfall annually. The predominant vegetation types are shrubland, dwarf shrubland and annual grassland. Woodland, bushland and perennial grassland occur along seasonal rivers and on the slopes of Mt. Marsabit to the East and the Ndoto Mountains to the West of the Rendille home range.

The vast majority of the Rendille population of almost close to 11,000 depends on pastoral livestock production which is almost entirely subsistence oriented. The dominant land use form is best described as horizontal nomadism although a number of impoverished families practice sedentary pastoralism in the vicinity of permanent settlements. The Rendille keep camels, sheep and goats and, where pasture permits it, cattle. They rely heavily on their camels for the production of their staple food, milk. Sixty to 90 percent of their diet is milk, depending on season and availability of such
imported foods as maize meal and sugar. About 80 percent of the milk consumed is camel milk (Schwartz, 1979) since that of other domestic stock is available only seasonally.

Food Supply

With the exception of certain ritual occasions camels are rarely slaughtered, but animals which die by accident or of a natural cause are normally butchered and their meat is consumed. A more regular meat supply is derived from sheep and goats which are slaughtered mainly in the dry season to complement the milk supply. It is common practice to bleed camels, usually immature animals between two and four years old. The blood is mostly consumed either whole or mixed with milk by the young men who do the herding away from the settlements. Depending on the frequency of bleeding the annual blood yield from a single camel can be as much as 35 l. Although camels are never used for riding they fulfil important transport functions. They carry houses and household goods when a settlement is shifting to a new location and they carry water for domestic use to the settlements. Compared to the milk, blood and meat production this seems to be a minor contribution to the pastoral economy, yet it determines to a large extent land use patterns and pasture utilization.

Management

The most prominent feature of the stock management and pasture utilization of the Rendille and a number of other pastoral tribes in East Africa is the division of the herds into househerds and 'fora' herds. The househerds are kept in the settlements to provide for the needs of the majority of the population, women, children and older men. They comprise fresh lactating females with their young; females due to give birth; some animals for slaughter and, occasionally, sick animals. Househerds graze in the vicinity of the settlements and shift
to new pastures only when the settlement moves, which can be as often as six times a year or as seldom as once every five years. The fora herds, which are tended by boys and young men combine the weaned immatures, pregnant females, females in late lactation, slaughter animals and breeding stock. Fora herds are highly mobile, exploiting pastures up to 100 km distant from the settlement and changing location according to the pasture conditions at very short intervals. Only after a good rainy season and for some ritual occasions do the fora herds return to the settlements, at which times animals are transferred from one herding unit to the other.

The movements of settlements and househerds within the Rendille home range and the seasonal fluctuations in the size of the househerds have been recorded by means of aerial surveys at two month intervals since June 1978. A preliminary analysis of the first seven surveys covering the period from June 1978 to June 1979 is shown in Map 1. The number of nomadic settlements in each respective quadrant of the map grid (10 by 10 km) multiplied by the duration of occupation in months was used to describe the annual occupation density. The map shows clearly that large areas of the home range have not been occupied at all by settlements during the observation interval, whereas two small areas (G/H, 8/9 and H/I, 2/3) have been very heavily utilized. If compared with Map 2, which gives a rough classification of the rangeland in rainy season, transition, and dry season pasture, it becomes obvious that the highest occupation density occurs on rainy season pasture, i.e. the poorest pasture. With the exception of a narrow strip in the southern part of the study area only rainy season pastures have been utilized by settlements. A simple explanation is given in Map 3 which shows the locations of permanent water sources like boreholes and wells. In all cases high occupation densities coincide with the location of permanent water sources. The only exception in this picture is the block E/F/G, 6/7 which was settled after the long rains March - May 1978 when rain water was available in a number of natural catchments.
These very high occupation densities around the permanent water sources have caused severe local degradation of vegetation and soils, a familiar process in arid and semi-arid areas. Although the deterioration of the pastures in the vicinity of permanent water is marked, the Rendille settlements seem to have encroached closer to the permanent water sources with each dry season for the last decade. It is evident from records of the recent migration history of a number of Rendille settlements that the degree of mobility, the frequency of shifts to fresh pastures and the shift distances have steadily decreased (Grum, 1977; Sobania, 1979). The pastoralists claim that this is due to the lack of loading camels, many of which died during the long drought from 1969 to 1976. Unfortunately there are no reliable figures available for the past or present camel population in Northern Kenya, but the various estimates suggest that camel numbers between 1969 and 1976 might have been reduced by as much as 50 percent of the pre-drought total. Considering the management practices of most of the camel-keeping pastoral groups in Northern Kenya it is clear that the losses of loading animals, i.e. adult castrates, must have been disproportionately higher and that the recovery of numbers in this group is slower than in others.

Usually the male calf faces a stiffer competition with the herdsman for the dam's milk than the female calf which, even in times of famine, will get a modicum of milk. Juvenile males are bled more frequently than females, in famine times occasionally to total exhaustion. This can result in a high mortality in male calves up to three years of age. The mortality after castration, usually at four years, is in the order of 3 percent. The adult castrate between six and seven years is the only camel which can be slaughtered for ritual occasions or in times of famine. The loading camels, which are only the adult castrates, due to their permanent association with the settlements normally graze the poorest pastures in the vicinity of the settlements and lose a considerable proportion of the available grazing time to water
transport. Therefore for most of the year they are in poorer condition than the rest of the herd and are the first to succumb to the stress of prolonged drought.

Utilization of pasture

Table 1 shows the composition of camel herds in Northern Kenya as recorded at different times since 1969. Although these data were recorded in herds of different ethnic groups, there is a striking downward trend in the proportion of adult castrates in the herds. This, together with the reported overall losses, leads to the conclusion that the increasing immobilization of nomadic settlements and the consequent over-utilization of certain pasture areas are direct results of heavy losses of transport animals.

Diagram 1 shows the distance between 31 Rendille settlements and the nearest permanent water source, as related to the average number of camels per household in the respective settlements. This was recorded on 28 August 1979, in the middle of the dry season, which lasts from May to October. All settlements with less than three camels per household were located within 2.5 km from the water source. Five out of eight settlements with three to six camels per household were at or beyond five km from water, and four out of eight with more than six camels per household settled at or beyond eight km from the water source.

The fact that settlements with low numbers of camels are all located near the water source, whereas those with larger numbers choose from a wider range of settling distances, indicates that the choice of dry season settlement site, and of dry season pasture for the househerd, is severely limited if the stock numbers per economic unit are too low. A simplified model (Table 2) demonstrates the relation between number of camels per household, maximum settling distance from a single water source and the potential area of utilization by settlement and househerds. It is assumed for the calculation that
- One camel can transport 120 l of water when saddle and water containers weigh approximately 30 kg;

- The daily water requirement of a Rendille household (4.3 persons) is 30 l;

- the walking pace of a camel is 5 km/h;

- the time required to fill the water containers is one hour;

- the available grazing time is 12 hours per day;

- and the recommended ratio working time: feeding time should equal 1:3 if the transport animal remains in a reasonable condition throughout the dry season.

Assuming that all 14.3 percent adult castrates in the herds (Table 1, 1979) are trained loading animals only those households with seven or more camels will be able to utilize the full potential pasture area.

Households with less than two camels will have to settle within walking distance from the water, which is at most 2.5 km.

In Map 3 the different maximum settling distances are indicated around a cluster of water sources in G/H, 8/9. It becomes obvious that settlements within the 5 km range are virtually confined to this range, whereas settlements at and beyond the 12.5 km range can reach numerous other water sources and can therefore adapt their movements much better to the actual pasture conditions.

Conclusions

Although sufficient firm data are not yet available to quantify the effect which higher mobility has on overall productivity of the herds, it is possible to conclude that:

- househerds kept within the 5 km range from water are commonly on the poorest pasture, the milk yields
are generally lower and the persistence of milk production through the dry season is greatly inferior to that of comparable animals beyond the 12.5 km range;

- the burden of intestinal parasites (mainly helminths) and of ectoparasites (mainly ticks) is, throughout the year, higher in herds kept on the much frequented pastures in the vicinity of permanent water;

- settlements within the 5 km range usually send a larger proportion of their already small herds to 'fora' camp than others to allow their animals the benefit of the distant pasture. They thus voluntarily deprive themselves of the much needed milk in the dry season for the sake of the better survival of their herds. Famine, although a seasonal occurrence in all of Rendille, is much more pronounced in the immobilised settlements.
Table 1: Composition of camel herds in Northern Kenya (%) kept by different ethnic groups

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<tbody>
<tr>
<td>Source</td>
<td>(Torry)</td>
<td>(Bremaud)</td>
<td>(Sato)</td>
<td>(Fratkin)</td>
<td>(Schwartz)</td>
</tr>
<tr>
<td>Ethnic group</td>
<td>Gabbra</td>
<td>Gabbra</td>
<td>Rendille</td>
<td>Ariaal</td>
<td>Rendille</td>
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<tr>
<td>Mature Males</td>
<td>2.9</td>
<td>4.5</td>
<td>3.3</td>
<td>7.2</td>
<td>4.5</td>
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<td>Castrates</td>
<td>22.0</td>
<td>22.4</td>
<td>14.5</td>
<td>9.3</td>
<td>14.3</td>
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<tr>
<td>Females</td>
<td>41.2</td>
<td>39.3</td>
<td>61.5</td>
<td>66.6</td>
<td>61.2</td>
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<tr>
<td>Juvenile Males</td>
<td>16.3$^{+}$</td>
<td>16.4$^{+}$</td>
<td>8.3$^{+}$</td>
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<td></td>
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<tr>
<td>Females</td>
<td>17.4$^{++}$</td>
<td>17.6$^{++}$</td>
<td>8.3$^{++}$</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>17.4$^{++}$</td>
<td>17.6$^{++}$</td>
<td>8.3$^{++}$</td>
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<tr>
<td>Infant Males</td>
<td>4.4</td>
<td>6.7</td>
<td>9.2</td>
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</table>

$^{+}$ includes infant males  $^{++}$ includes infant females

Table 2: Relation between number of loading camels per household, maximum settling distance from a single water source (km) and potential area of utilization (km$^2$)

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<th>Camels per household</th>
<th>nil</th>
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<tr>
<td>Frequency of water transport</td>
<td>daily</td>
<td>daily</td>
<td>2 days</td>
<td>4 days</td>
</tr>
<tr>
<td>Maximum settling distance</td>
<td>2.5</td>
<td>5</td>
<td>12.5</td>
<td>27.5</td>
</tr>
<tr>
<td>Potential area of utilization</td>
<td>177</td>
<td>314</td>
<td>962</td>
<td>3318</td>
</tr>
</tbody>
</table>
Map 2: Classification of seasonal pasture modified after FAO rangeland survey 1971.
Diagram 1: Relation between number of househerd camels per household and distance between the nearest permanent water source and the settlement. (31 settlements recorded on 28 August 1978)
REFERENCES


Sato, S. 1976 Personal communication.


SECTION B

CAMEL MILK AND MEAT PRODUCTION
THE MILCH DROMEDARY

Karl Horst Knoess

Summary

Although knowledge on the production of the dromedary is incomplete, available data show that this species has a potential for milk production. The dromedary can produce large quantities of milk under both extensive and intensive management systems. Daily milk yields of 15 to 40 kg, which represents 3.3 to 8.9 percent of body weight, have been observed. The camel is in many areas the only livestock species able to utilize arid pastures and deserts for producing milk, meat, wool and hair. Unlike imported exotic livestock the camel can be reared under arid conditions. Camels are less damaging to the environment than other livestock species.

Introduction

The dromedary (Plate 1) populates the semiarid and arid tropical and subtropical regions of Africa and Asia, and has also been successfully introduced to other regions such as Australia.

The bactrian or two-humped camel is bred in the cold regions of Asia, while the dromedary is better adapted to a hot desert climate. The bactrian camel excels in areas with extremely cold winters and is well suited to the high mountainous regions of Inner Asia.

The domestication of camels made it possible for human populations to spread to deserts, steppes and arid regions, such as those of north and east Africa, the Arabian Peninsula, the Near East, India, and Inner Asia.
The camel provided man with animal protein and energy, and rendered the nomads independent of agriculture providing them with mobility.

There is evidence that the dromedary was domesticated by the Semites, especially the Arabs, by 1800 B.C. in the border lands of Arabia (Epstein and Mason, 1971).

In the Holy Quran the camel is several times mentioned as a blessed animal given to man. Camels should not be ill treated. The slaughter and eating of camels is regarded as a profession of Islamic faith in the Near East where the avoidance of camel flesh is usually found among the non-Muslim communities, such as Jews, the Zoroastrians of Iran, the Christian Copts of Egypt and the Christian Ethiopians. In India camel meat is not eaten by Hindus (Simoons, 1961).

From early times as a beast of burden the camel facilitated trade between countries and continents. In Africa the camel caravans connected north Africa with the regions south of the Sahara and with east Africa. Near East countries communicated with India, inner Asia, Tibet and China by camel.

As an animal for riding and a beast of burden the camel has lost some of its importance where motor transport is available. Nowadays most places in north Africa and the Near East can be reached by motorized transport. The high costs of leading and herding make camel transport expensive. In other countries, such as Afghanistan, Pakistan, and India, Somalia and Ethiopia, with no cheap sources of fuel and with available low-salaried labour in areas which are frequently unsuited to motor transport, the camel has retained its role as a baggage animal. (Plate 2) This situation has kept the price of baggage camels high. In lowland Ethiopia a fully grown male dromedary costs the equivalent of between 200 and 500 US dollars. In the Indian province of Punjab a fully grown baggage camel will fetch between 400 and 800 US dollars. These camels are used for carrying loads of
up to 550-600 kg and pulling carts loaded with grain, fodder, cotton, bricks, wood, steel girders, pipes etc. Camels are not only used on tracks unsuited to motorized transport but also on the highways. In towns, camel carts share the transport with ox carts, and with donkeys, mules and horses (Plate 3). Increasing fuel prices may ultimately cause a re-emergence of the transport camel in countries where its role was gradually being reduced.

In some regions the expansion of agriculture has reduced the grazing area of nomad camel herds. In places where the agricultural area has been increased under rain-fed conditions with low and uncertain rainfall the result is often devastating. Well adapted vegetation consisting of shrubs, trees and perennial grasses has been destroyed by cultivation leaving the soil open to the forces of erosion and resulting in the ultimate loss of any production potential be it through agriculture or livestock. Under uncultivated conditions nomadic or seminomadic utilization of land is more productive than attempted agriculture.

In the case of irrigated agriculture, as in some parts of Ethiopia, Egypt, Pakistan and India, traditional camel rearing methods require modification.

Camel husbandry is also influenced by the voluntary migration of people from agricultural and pastoral areas to towns and centres of industry. This has affected the camel industry, especially in the Arab oil-producing countries where camel rearing is no longer considered sufficiently profitable or socially acceptable. Camels are left without herders or management. This situation has to be seen in the general context of a crisis of culture. The old values and traditions, in which the camel was firmly established, are being impaired. European civilization and values have become the yardstick of life. Consumer goods and high-producing exotic livestock are considered superior.

The neglect of camels in countries of north Africa
and the Middle East is aggravated by persuasive salesmen from developed countries who are keen to sell livestock, especially cattle. Their objective is selling and they usually do not consider alternative solutions with camels. A number of countries, where there are nomads of diverse ethnic origin, have tried to settle them often with the sole aim of keeping them under control. Where arable land, water, financial resources and good will are available settlement programmes can succeed though the steppes and deserts will not then be utilized. Lacking these basic requirements no settlement scheme can be successful.

During the past century immense progress in animal husbandry has been achieved in the developed countries. The production of all animal products has been greatly increased through research, breeding, and improved feeding and marketing.

In the camel-owning countries there have been few if any attempts to improve the productivity of the indigenous livestock. The progress of the livestock industry in the developed countries created a general prejudice against the value of animals in the developing countries which was shared by experts and policy makers in both camps. The camel is faced with a double set of prejudices. It is not only considered to be of low economic value as compared with exotic livestock but is also seen as part of an old-fashioned, obsolete nomadic or seminomadic civilization. Rarely were attempts made to evaluate the production potential of camels. The animal was seen as of transitory value to be substituted by other, more productive livestock.

Substantial research has been conducted into the physiology and diseases of camels and provides a basis for the development and reorientation of the camel industry.
Milk yields

Knowledge of the milk yields of dromedaries is incomplete and fragmentary. Complete lactations with regular test milkings have not been recorded. However, from the limited information available it can be concluded that camels have the potential to be high producers of milk. Table I provides data on milk yields from various sources.

Daily yields of 3.5 kg to 35 kg can be noted. The author has observed one female camel which yielded close to 40 kg per day. This particular animal, together with other female camels, had been bought by the Kingdom of Saudi Arabia from Pakistan. Table I provides important information on the daily milk yield in relation to the body weight of the camel: the percentage values vary from 1.3 to 7.8. The higher this value the higher is the feed conversion efficiency. Camels are seldom fed as well as high producing cattle and they are not usually selected for high production as cattle are in developed countries. Some nomadic tribes such as the Somali and the Afar have selected camels for milk production but the methods of selection cannot be compared with those employed for exotic livestock. The yields quoted in Table I are considered to be rather conservative by the present author who has experience of milch camels in Ethiopia, Kenya, Libya and Pakistan.

Table 2 shows the results of trials conducted with camels in the Awash valley of Ethiopia (Knoess, 1976).

The average daily milk yield of this camel during these 5 months was 8.1 kg with twice daily milking. This particular camel could have a minimum lactation yield of 2471 kg in 305 days. The animal was purchased locally and was not a notably high producing animal. Usually the Afar in this region do not sell female camels. On the research station the camel was allowed to graze irrigated alfalfa pasture ad lib. consuming 50.2 kg of fresh alfalfa each day over five days. It
showed no sign of bloat or other discomfort. Sheep and goats on such pasture would suffer losses due to bloat.

Seven camels, at various stages of lactation from 6 to 14 months were milked twice daily. The average of the highest daily yield was 6.69 kg, ranging from 3.2 to 10.4 kg. They grazed freely on an irrigated pasture of over-mature Panicum maximum. Unfortunately these animals were under trial for only one month. The author has observed camels giving 13 kg per day under rainfed conditions in the arid Awash Valley.

In 1981 the milk yields of 5 milk/baggage camels in Punjab were recorded over a period of 305 days. They calved in February and produced an average of 19.7 kg of milk per day with a total yield of 6008.5 litres. Immediately after calving the total daily yield was almost 30 kg and the average over 10 months was 17.4 kg per day. In early lactation the fat content was 4.2 percent: this declined to 2.5 percent in the hot season and rose to 3.5 percent in the cool month of December. The average liveweight of these camels in December 1981 was 604 kg. (Plates 4, 5, 6)

Frequent milking increases the yield. If nomadic camels graze far from any water source they will be milked only when the attendants feel hungry or thirsty.

The composition of camel milk as quoted by various sources is given in Table 3. The milk compositions of water buffalo, Friesian cow and two goat breeds and one sheep breed are given for comparison. The amounts of protein, fat and lactose are in the range of the Friesian cow. The contents for the buffalo and sheep are higher and for the Afar goat lower. The vitamin C content of camel milk is generally regarded as high. The amount indicated in Table 3 is higher than for the cow, goat and sheep but does not reach the higher level of buffalo milk.
The type of forage or feed and amount and frequency of water available influence the yield, composition and taste of the milk. Succulent fodder usually increases the milk yield. Some plants on natural pastures cause a bitter taste. The type of forage influences the mineral and trace element contents. The camel is very sensitive to lack of salt. Nomads know which pastures are beneficial to their camel herds and change the pastures accordingly; other camel breeders provide minerals or at least add salt to the rations.

The time of conception, and accordingly the time of calving influences lactation and yield. The calving interval determines productivity. Early weaning in order to reduce the calving interval is technically possible but is rarely done.

Deficiency diseases and infections and parasitisms also influence the milk production.

Utilization of camel milk

In some countries dromedary milk is considered to have therapeutic properties. In India it is supposed to cure dropsy, jaundice, spleen trouble, tuberculosis and asthma. In parts of Ethiopia camel milk is considered to have an aphrodisiac effect. In Ethiopia it is usually drunk fresh. The Afar do not allow processing or sale of camel milk. The Somali sell camel milk in towns. In India some camel milk which is not drunk fresh is fermented to produce kemiss. It has been reported that sometimes surplus camel milk is given to horses and foals. Butter, ghee, curd and cheese can be prepared from camel milk, but most of it is consumed fresh.

Proposals for improved camel production

Improved camel management should benefit the breeder, the socio-economy, and the ecology of the country.
Camel husbandry should be given a new impetus to ensure its rightful place in the livestock economy.

Deserts and steppes should not be depopulated and erosion should be prevented. The settlement of nomads often results in negative effects such as over-grazing around settlements while outlying pastures are unused. This results in deterioration of livestock and erosion of pastures. The settled life very often means physical and moral decadence for the nomad unless he can find another profitable income. Once the nomad abandons his way of life neither he nor his descendants will ever become nomads again.

Deserts and steppes can be utilized only by nomadic flocks. Nomadic life has to be made more attractive by providing certain essential utilities such as schooling and medical services. The creation of marketing channels should enable the breeder to get a good price for his livestock. The provision of too many wells, intended to tempt the nomads to reduce their migration, damages the pastures. Evaluation of carrying capacity is necessary and the number of animals should be retained at a safe level. A natural pasture consisting of grasses, herbs, shrubs, bushes and trees has a lower carrying capacity for cattle and sheep than for camels which can utilize a wider range of plants and therefore derive more nutrition. Efforts have to be made in arid regions to improve and reclaim eroded and over-grazed pastures. This can only be achieved by controlled pasture management, reseeding, and afforestation. In deserts and steppes it is important to maintain sufficient camels to ensure the supply of milk and meat and to retain sufficient mobility.

In rainfed agriculture the camel can provide more milk for home consumption and sale than any other domestic animal. However, milch camels must not be introduced if the population is prejudiced against camel milk.
Surplus male camels can be used for work or fattening. If camel milk cannot be sold it can be used for home consumption to free the milk of other species for sale. The camels can graze those pastures which cannot be utilized by other species. If suitable pasture for camels is available an interaction between extensive grazing of males and dry females with more intensive feeding of lactating females can be organized. A variety of agricultural byproducts can be fed to camels. Intensive irrigated forage production introduced in some oil-rich countries for exotic cattle could also be utilized for camel milk production. This would have the following advantages:

1. saving investment costs since camels do not need the same level of management as exotic cattle to protect them from the climate;

2. camels will increase their production with good feeding while the production of exotic cattle will fall due to unavoidable stresses;

3. while imported high-yielding milch cattle need a high level of nutrition and management, the camel can be reared under nomadic or extensive conditions from weaning to lactation and once the females are dry they can be returned to the rainfed pasture;

4. in order to maintain a herd of high yielding cattle, frequent imports of breeding stock are necessary to avoid inbreeding and the consequent reduction of performance. There should be sufficient numbers of camels to avoid in-breeding;

5. the management and handling of camels does not require foreign expertise;

6. camel breeding, being based on the resources of the country, is less vulnerable to economic changes and disasters.
In order to increase the production of camel milk and meat, breeding management, disease control, and improved feeding and marketing are necessary.

The general principles of breeding as applied to other livestock can be employed with camels. They entail selection and cross breeding for higher performance. Success will depend on adequate planning and supervision.

Research on camel production is urgently needed. This research should be aimed at increasing production and reducing the losses caused by disease and parasites. Efforts have to be made to reduce the calving interval through early weaning and early conception after calving. The problem of seasonable breeding calls for investigation. Conceptions take place outside the breeding season, indicating that the season can be extended.

Comparison of forage requirements and management for dairy cattle and dairy camels in an arid area. 13 000 camels and 13 000 cows.

Assumptions:

<table>
<thead>
<tr>
<th>Type of irrigated pasture:</th>
<th>pure lucerne pasture for grazing or cut-and-carry;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of rainfed pasture:</td>
<td>natural pastures consisting of grasses, bushes, small trees and cactus;</td>
</tr>
<tr>
<td>Management of irrigated pasture:</td>
<td>grazing or cutting interval: 28 days; introduction in one year: 135 000 kg fresh green matter, or 27 000 FU (feed units);</td>
</tr>
<tr>
<td>Type of dairy cattle:</td>
<td><em>Bos taurus</em> giving a daily average milk yield of 15 kg, adult body weight 450 kg, age at first calving 24 months;</td>
</tr>
<tr>
<td>FU requirement, considered per unit in camel and cow:</td>
<td>100 kg live weight = 0.84 FU for one day (Bogner, 1968); 459 kg live weight = 3.8 FU for one day; 1 kg milk with 4 percent fat = 0.36 FU;</td>
</tr>
</tbody>
</table>
Composition of herds:  
Female dairy cattle: Total 1,300
- adult females: 780
- dry females: 195
- lactating females: 585
- female calves and heifers under 12 months: 520
- males under 12 months: 260

Female dairy camels: Total 1,300
- adult females: 780
- dry females: 390
- lactating females: 390
- young females under 42 months: 520
- males under 12 months: 173.3

Mortality and losses: It is assumed that mortality and losses are equal in both species: they have not been assessed.

Housing and management: Cattle are housed in sheds with special arrangements for cooling. They can only graze by night and at early morning and evening. Camels need no housing but shade should be available during rest periods. They can graze at any time of the day or night. For cattle the cut-and-carry system might prove necessary.

All 1,300 female cattle, and 260 young males to the age of 12 months when they can be slaughtered, will be maintained on irrigated pastures. Of 1,300 female camels only 390 lactating females need irrigated pastures. The 170 male young camels to the age of 12 months will be reared on irrigated pastures, but this is strictly necessary only until weaning at the age of 8 months.
# Requirements of irrigated pastures and natural rainfed pastures for milk cattle and camels

<table>
<thead>
<tr>
<th>Pasture Type</th>
<th>Cattle (Ha/year)</th>
<th>Camels (PU/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement of irrigated pastures</td>
<td>1 167</td>
<td>50.7</td>
</tr>
<tr>
<td>Rainfall of 250–300 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>137 FU/ha/year</td>
<td></td>
<td>5 722.2</td>
</tr>
<tr>
<td>Rainfall of 200–250 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 FU/ha/year</td>
<td></td>
<td>8 710.4</td>
</tr>
<tr>
<td>Rainfall of 150–200 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52 FU/ha/year</td>
<td></td>
<td>15 075.8</td>
</tr>
<tr>
<td>Rainfall of 100–150 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62 FU/ha/year</td>
<td></td>
<td>12 644.2</td>
</tr>
<tr>
<td>Rainfall of 50–100 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 FU/ha/year</td>
<td></td>
<td>52 262.6</td>
</tr>
</tbody>
</table>

(Ginzburger and Bayoumi, 1977)

- Milk production of each herd: tons per year: 3 202.9, 2 135.3
- Milk production per ha per year in tons: 2.7, 4.2
<table>
<thead>
<tr>
<th>Country</th>
<th>Average body wt.</th>
<th>Av. daily yield</th>
<th>Av. lact. yield</th>
<th>Av. lact. length</th>
<th>Av. daily yield as % of body wt.</th>
<th>Calculated av. lact. yield of 305 days</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egypt</td>
<td>380-400</td>
<td>3.5-4.5</td>
<td>1600-4000</td>
<td>-</td>
<td>-</td>
<td>1068-1373</td>
<td>El Bahay 1962</td>
</tr>
<tr>
<td>Libya</td>
<td>380-400</td>
<td>8.3-10</td>
<td>2700-4000</td>
<td>9-16</td>
<td>2.2-2.6</td>
<td>2532-3050</td>
<td>G.E.F.L., 1977</td>
</tr>
<tr>
<td>Libya</td>
<td>400</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>2.5</td>
<td>3050</td>
<td>Nagi A, Abu Daia and Hamadani, O.</td>
</tr>
<tr>
<td>Somalia</td>
<td>350</td>
<td>5</td>
<td>1950</td>
<td>13</td>
<td>1.4</td>
<td>1525</td>
<td>Abdullahi Moh. 1973</td>
</tr>
<tr>
<td>Tunisia</td>
<td>4</td>
<td>12</td>
<td>-</td>
<td>12</td>
<td>1220</td>
<td></td>
<td>Burgemeister, R. 1974</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>360</td>
<td>5-13</td>
<td>1872-2592</td>
<td>12-18</td>
<td>1.4-3.6</td>
<td>1525-3965</td>
<td>Knoess, K.H. 1977</td>
</tr>
<tr>
<td>Pakistan</td>
<td>3.5-13.5</td>
<td>1350-3660</td>
<td>-</td>
<td>-</td>
<td></td>
<td>1068-4118</td>
<td>Yasin S.A. and Wahid, A. 1957</td>
</tr>
<tr>
<td>Pakistan</td>
<td>6.7-10</td>
<td>2700-3600</td>
<td>9-18</td>
<td>-</td>
<td></td>
<td>2044-3050</td>
<td>Leupold, J. 1968</td>
</tr>
<tr>
<td>Pakistan</td>
<td>450 (heavy)</td>
<td>15-35</td>
<td>5475-12775</td>
<td>12</td>
<td>3.3-7.8</td>
<td>4575-10675</td>
<td>Knoess, K.H. 1979</td>
</tr>
<tr>
<td>Pakistan</td>
<td>350 (desert)</td>
<td>8-10</td>
<td>2920-3650</td>
<td>12</td>
<td>2.3-2.9</td>
<td>2440-3050</td>
<td>Knoess, K.H. 1979</td>
</tr>
<tr>
<td>India</td>
<td>350 (desert)</td>
<td>4.5-9.1</td>
<td>2430-4914</td>
<td>18</td>
<td>1.3-2.6</td>
<td>1373-2776</td>
<td>Rao, C.K. 1973</td>
</tr>
<tr>
<td>India</td>
<td>450 (heavy)</td>
<td>6.9-18.2</td>
<td>3105-8190</td>
<td>15</td>
<td>1.5-4.0</td>
<td>2105-5551</td>
<td>Rao, C.K. 1974</td>
</tr>
<tr>
<td>India</td>
<td>-</td>
<td>10.8</td>
<td>-</td>
<td>-</td>
<td></td>
<td>3294</td>
<td>India, 1970</td>
</tr>
<tr>
<td>China</td>
<td>-</td>
<td>7.5</td>
<td>3300</td>
<td>16-17</td>
<td></td>
<td>2288</td>
<td>Ensminger, M.E. and Ensminger, A. 1973</td>
</tr>
</tbody>
</table>
Table 2: Average daily milk yields during different stages of lactation. (Body weight of female adult camel 360 kg.)

<table>
<thead>
<tr>
<th></th>
<th>Daily yield kg</th>
<th>Yield as percentage of body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>10th month of lactation, December</td>
<td>7.2 - 8.4</td>
<td>2.0 - 2.3</td>
</tr>
<tr>
<td>11th month of lactation, January</td>
<td>8.0 - 9.0</td>
<td>2.2 - 2.5</td>
</tr>
<tr>
<td>14th month of lactation</td>
<td>6.8 - 8.8</td>
<td>1.9 - 2.4</td>
</tr>
</tbody>
</table>
### Table 3: Milk composition

<table>
<thead>
<tr>
<th></th>
<th>Dromedary 1</th>
<th>Dromedary 2</th>
<th>Average drom.</th>
<th>Buffalo</th>
<th>Frisian</th>
<th>Afar goats</th>
<th>Brit. goats</th>
<th>Afar sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>87.6</td>
<td>88.5</td>
<td>87.9</td>
<td>85.6</td>
<td>87.4</td>
<td>83.23</td>
<td>87.85</td>
<td>88.2</td>
</tr>
<tr>
<td>Ash</td>
<td>0.77</td>
<td>0.7</td>
<td>0.76</td>
<td>0.9</td>
<td>0.6</td>
<td>0.75</td>
<td>0.6</td>
<td>0.79</td>
</tr>
<tr>
<td>Protein</td>
<td>3.9</td>
<td>2.0</td>
<td>3.5</td>
<td>4.5</td>
<td>3.7</td>
<td>3.52</td>
<td>3.78</td>
<td>3.25</td>
</tr>
<tr>
<td>Ether extracted fat</td>
<td>2.9</td>
<td>4.1</td>
<td>4.6 - 4.7</td>
<td>3.8</td>
<td>5.5</td>
<td>2.9</td>
<td>7.45</td>
<td>3.5</td>
</tr>
<tr>
<td>Lactose</td>
<td>5.4</td>
<td>4.7</td>
<td>3.9</td>
<td>4.88</td>
<td>5.4</td>
<td>4.68</td>
<td>4.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Calcium mg/100 g</td>
<td>94</td>
<td>40</td>
<td>113</td>
<td></td>
<td></td>
<td>144</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorous mg/100 g</td>
<td>86</td>
<td>138</td>
<td>97</td>
<td></td>
<td></td>
<td>122</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td></td>
<td>0.5</td>
<td></td>
<td></td>
<td>0.38</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>Thiamin</td>
<td></td>
<td></td>
<td>0.06</td>
<td></td>
<td></td>
<td>0.09</td>
<td>0.04</td>
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</tr>
<tr>
<td>Riboflavin</td>
<td></td>
<td></td>
<td>0.08</td>
<td></td>
<td></td>
<td>0.03</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td></td>
<td></td>
<td>2.3</td>
<td></td>
<td></td>
<td>1.95 -</td>
<td>0.78</td>
<td>1.97</td>
</tr>
<tr>
<td>Total solids</td>
<td>13.0</td>
<td>12.12</td>
<td>14.4</td>
<td></td>
<td></td>
<td>13.17</td>
<td>16.77</td>
<td>12.15</td>
</tr>
<tr>
<td>Solids non-fat</td>
<td>10.1</td>
<td></td>
<td>8.9</td>
<td></td>
<td></td>
<td>9.5</td>
<td>9.32</td>
<td>8.65</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td>6.63-(10)</td>
<td></td>
<td></td>
<td>6.53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Ohri and Joshi, 1961.
6. Knoess, 1976. (Milk samples analysed by Ethiopian Nutritional Institute, Addis Ababa.)
7. Leitch, 1940.
10. Albonico et al., 1967-68.
REFERENCES

Albonico F. et al. 1967-68. Buffalo milk studies;  
I. Composition of bulk milk pro- 
duced in different regions under 
various husbandry conditions. Indust- 
ria Latte 3: 221-226. 4: 10-20.

Barakat M.Z. Abdel Wahab M.F. 1961. The ascorbic acid 
content of milk. Vet. Med. J. Giza 7, 
275-280.

Bogner, H 1968 Das Rind. D L V Verlag. Frankfurt-
am-Main.

Diss., Giessen.

El-Bahay, C.M., 1962. Normal contents of Egyptian camel 

Ensminger, M.E. and Ensminger, A. 1973. China, the 
impossible dream. Agriservices 
Foundation, Clovis, California.

Epstein, H. and Mason, J.L. 1971. The origin of the 
domestic animals of Africa. Edition 
Leipzig.

FAO / US Department of Agriculture. 1968. Food compos- 
tion tables for use in Africa. 
FAO. Rome, Italy.

G.E.F.L. Groupement d'Etude Francais en Libye. Survey 
for the development of the central 
Wadi Zone and Gulf of SIRTE. Crazing 
project 2. Flock Management Report.

Gintzburger, G. and 
Bayoumi, M. 1977. Survey of the 
present situation and production of 
the Libyan Rangelands Agricultural 
Research Center. Natural Resources 
Unit, Libya.

India 1970 The wealth of India. Vol. VI. Live-
stock. Council of Scientific and 
Industrial Research, New Delhi.

Knoess, K.H. 1976 Assignment report on animal production 
in the Middle Awash Valley, FAO. 
Rome, Italy.

" 1977 The camel as a meat and milk animal. 
World Animal Review No. 22. FAO, 
Rome, Italy.

" 1979 Observations on camels in Pakistan 
(unpub.)

Kon, S.K. 1959 Milk and milk products in human 
nutrition. FAO Nutritional Studies 
No. 17, Rome, Italy.

Leese, A.S. 1927 A treatise on the one humped camel 
in health and in disease. Haynes and 
Son, Stamford, England.

Leitch, I. 1940 The feeding of camels. Technical 
Nutr., England.

Leopold, J. 1968 Le chameau.—Important animal dome-
bleus. Vet. 15.

Nagi, A., Abu Daia, M., and Hamadani, O. Secretariat 
of Agriculture. Agrarian Sheep 
Project, Libya.


" 1974 Scheme for the improvement of Indian camel. Animal Husbandry Commission, India.


Plate 1: The dromedary of Africa and Asia (Photo K.H. Knoess)

Plate 2: Baggage camel, Punjab. (Photo: K.H. Knoess)
Plate 3: Camel cartage. Punjab, Pakistan. (Photo K.H. Knoess)

Plate 4: Camel udder. Punjab, Pakistan. (Photo K.H. Knoess)
Plate 5: Camel milking. Punjab, Pakistan. (Photo K.H. Knoess)

Plate 6: Female milk and baggage camel in Punjab, Pakistan. Body length 1.61 m. (Photo K.H. Knoess)
THE PRODUCTION AND UTILIZATION OF CAMEL MILK

by M.R. Shalash

Introduction

Camel husbandry is influenced by the voluntary migration of people from agricultural and pastoral areas to towns and industrial centres. This has adversely affected the camel industry, especially in the oil-producing countries where camel breeding is no longer considered economically or socially acceptable.

During the last century, the production of milk, meat and other animal products has greatly increased in the developed countries through research, breeding and improved feeding and marketing. In the countries where camels are indigenous there have, unfortunately, been few achievements in increasing the productivity of any of the livestock.

The neglect of camels can be attributed to a double set of prejudices. The animal is often considered to be of low economic value compared with exotic livestock, and is seen as belonging to an archaic civilization. Few economic and biological evaluations of camels in terms of productive and reproductive potentials have been attempted, although substantial research has been conducted in the fields of physiology and disease control. This research forms a basis from which further development and reorientation of the camel industry may begin.

The present review is an attempt at a preliminary evaluation of current knowledge concerning the milk production potential of the camel as influenced by environmental and hereditary factors considering milking and milk consumption as well as nutritive value.
Milk yield

Knowledge concerning the milk yield of camels is incomplete owing to the difficulty of estimating daily milk yields under pastoral conditions. Complete lactations are not recorded and there is no regular milk testing.

Knoess (1979) observed that a number of camel breeds have the potential to be high producers of milk, yielding from 3.5 kg to 35 kg per animal daily. He recorded one female camel as yielding close to 40 kg per day. This particular animal, and some other female camels, had been bought by the Kingdom of Saudi Arabia from Pakistan.

In general the yield varies with species, breed, individual, region, feeding and management conditions, stage of lactation (Dina and Klinteerg, 1977), type of work and milking frequency. Bactrian camels appear to be capable of producing up to 5 000 kg (11 000 lb) of milk per lactation period of from 6 to 18 months (Kulaeva, 1964; Dong Wei, 1979). The average production is probably within the range 800 to 1 200 kg though yields of 5 000 kg can be attained (Williamson and Payne, 1978). The percentage of butterfat in the milk of bactrian camels varies from 5.76 to 6.59 (Kulaeva, 1964). Well fed and managed dromedaries will produce from 2 722 to 3 629 kg of milk in a lactation period of 16 to 18 months, while under desert conditions the average lactation yield varies from 1 134 to 1 588 kg of milk in 9 months (Yasin and Wahid, 1957; Iwena, 1960). A good dam can yield 9 kg of milk daily at the peak of her lactation (Williamson and Payne, 1978). Leupold (1968) gave the average lactation production of Pakistan camels under poor nutrition as 2 700 - 3 600 kg, while the ITU (1973 a) estimate was 1 700 to 3 000 kg for the same camel type under desert and favourable conditions. Knoess (1976) estimated the potential lactation yield of Adal camels in Ethiopia maintained on irrigated pastures as 2 847 kg. Ashoub (1936) reported that the average daily milk yield of camels in Egypt is 2.5 kg and that the milk contains less fat but more sugar than cow milk.
According to Sharma and Bhargava (1963) the dromedary can give from 2.2 to 4.5 kg of milk daily for 7 to 8 months, while Leese (1927) stated that the amount of daily milk recovered during the first two weeks post-partum may vary from 4 to 9 kg in addition to that taken by the young calf.

The dromedary, like most other mammalian species, gives most milk near the beginning of the lactation period. In a study of the camels of northern Kenya, Field (1979a) estimated their daily yield at 21 kg in the second week of lactation, falling to 4.8 kg by the tenth week. One dam that had lost her calf only gave 2.2 and 3.7 kg at the two respective times. Bremaud (1969) and Knoess (1976) gave the maximum daily production of Somali and Adal camels as 12 and 10.4 kg respectively. Yasin and Wahid (1957) estimated that the Pakistan dromedary can produce 9.1 to 14.1 kg of milk when well fed. Williamson and Payne (1978) stated that the milk yield (over 16-18 months) of a good unspecified dam under favourable tropical conditions could reach 2 722 kg or more. Dahl and Hjort (1976) gave the average daily milk production of the east and north African camel as 3.5 to 4.0 kg during a lactation period of 9 to 18 months.

Duration of lactation

The average length of the lactation period in the camel is 12 months, but this is subject to wide variation as reported by various investigators. It may range in the dromedary from 9 to 18 months (Bremaud, 1969; Dahl and Hjort, 1976; Leese, 1927; Field, 1979b; Mares, 1954); from 16 to 18 months (Yasin and Wahid, 1957; Williamson and Payne, 1976); from 7 to 8 months (Sharma and Bhargava, 1963), and for 9 months (Iwena, 1960). Kulaeva (1964) reported a lactation in the Bactrian camel varying from 6 to 18 months. Dahl and Hjort (1976) have stated that Russian findings indicate that on rare occasions when camels calve every year a lactation period of 7 months is normal. Dong Wei (1979) reported that the lac-
tation period in Chinese bactrian camels lasts about 14 to 16 months.

Blagovescenskii (1963) stated that although the lactation period endures for 18 months the calf may be weaned at 8 to 10 months without adversely affecting its growth.

Frequency of milking

Under pastoral conditions, if nomadic camels travel far from any water sources, the shepherds will milk them whenever they feel hungry or thirsty (Knoess, 1979). Camels may be milked once a day by the Murrah of Arabia (Cole, 1975), from two to four times a day by the Somali (Bremaud, 1969; Hartley, 1979) and the Rendille of Kenya (Spencer, 1973), and as many as six or seven times by the Afar of Ethiopia (Knoess, 1977). The latter may also leave their animals unmilked for a whole day, which may account for the occasional high estimates of 13 kg milk per day.

Factors affecting milk yield

The milk yield of camels is influenced by a number of factors such as species, breed or type, age, stage and persistency of lactation, lactation number and length of the dry period, and state of nutrition and health. Increased incidence of the operation of milking increases the yield up to a certain limit. It is usual for female camels to be milked twice a day, but if milked 3 or 4 times a day an increase of 10 to 12 percent in milk production will result (Shalash, 1982). Knoess (1979) made some pertinent observations on the factors influencing lactation. He reported that:

1. The type of forage or feed and the ready availability of water influences the yield, composition and flavour of the milk. Succulent fodder usually increases the milk yield. Some plants on a natural pasture may cause the milk to have a strong flavour or even a
bitter taste. The type of forage determines the supply of the minerals and trace elements. The camel is very sensitive to lack of salt. Nomads know which pastures are beneficial to camels and alternate the grazing areas accordingly. Some camel breeders administer certain tonics regularly to their camels or as a routine add salt to the ration.

2. The time of conception and accordingly the calving time influence milk yield and duration of lactation. The calving interval determines milk production. Early weaning is feasible and reduces the calving interval, but is rarely done except inadvertently in the event of calf mortality.

3. Infectious and parasitic diseases and nutritional deficiencies also influence milk production either directly or indirectly.

Physical and chemical characters of milk

Camel milk is white in colour, has a salty taste and froths when shaken.

The pH ranges from 6.5 to 6.7 with an average value of $6.56 \pm 0.0102$, which resembles that of sheep. It is less alkaline than the milk of the cow or the water buffalo.

The mean specific gravity (1.0305) is lower than that of water buffalo, cow or sheep milk.

Camel milk has a greater freezing point depression ($-0.576^\circ$C), a fact which may be explained by its comparatively high chloride content.

The water content of camel milk ranges between 84 and 90 percent with a mean of $87.9 \pm 0.11$ (ITV, 1973a; Dahl and Hjort, 1976; Knoess, 1977; El Amin, 1979; Mukasa-Mugerwa, 1981). The total solids content of camel
milk is lower than that of the water buffalo, cow or sheep and shows some variation: 12.39 percent (Barthe, 1905); 12.4 percent (Brody, 1945); 13.45 percent (Davis and Macdonald, 1952); 13.01 percent (Yasin and Wahid, 1957); 14.3 percent (Knoess, 1977); 13.04 percent (Dahl and Hjort, 1976); 12.76 percent (ITVα, 1973); and 13.36 percent (Mukasa-Mugerwa, 1981).

Values for the fat content of camel milk vary between 3.5 percent and 5.5 percent (Dinkler, 1896; Leese, 1927; Davis, 1955; Davis and Macdonald, 1952; Yasin and Wahid, 1957; ITVν, 1973; Dahl and Hjort, 1976; Knoess, 1977; El Amin, 1979; Mukasa-Mugerwa, 1981). It has a lower fat content than that of the Egyptian water buffalo (El-Bahay, 1962) or the cow or ewe (Ensminger, 1969).

The ratio of fat to total solids in camel milk ranges from 20 to 43 percent with a mean of 31.16 which is near to that of cow milk (32.1 percent) but definitely lower than that of buffalo milk (40.91 percent). The mean S.N.F. and total nitrogen is 0.55 ± 0.106 and 0.47 respectively.

The protein content of camel milk ranges between 2 and 5.5 (Yasin and Wahid, 1957; El-Bahay, 1962; ITVα, 1973; Dahl and Hjort, 1976; Knoess, 1977; El Amin, 1979; Mukasa-Mugerwa, 1981) which is approximately the same as that of cow's milk but lower than that of the buffalo of ewe (Yasin and Wahid, 1957; El-Bahay, 1962). The mean casein content of camel milk is 2.6 ± 0.004 (El-Bahay, 1962). A comparative study was conducted by Hoeller and Hassan (1965): the results are shown in Table 1.

The value of chloride content for camel milk is 0.158 ± 0.001 which is higher than that of buffalo or cow milk (El-Bahay, 1962), while the ash lies between 0.6 and 1.0 percent with a mean of 0.76 ± 0.009 (El-Bahay, 1962; Yasin and Wahid, 1957; ITV, 1973a; Dahl and Hjort, 1976; Knoess, 1977; El-Amin, 1979; Mukasa-Mugerwa, 1981). This indicates that camel milk is generally richer in mineral content than that of the cow while sheep milk is the richest of all other ruminant animals (Table 2).
<table>
<thead>
<tr>
<th>Constituents</th>
<th>Camel</th>
<th>Cow</th>
<th>Goat</th>
<th>Water buffalo²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amino acids</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alanine</td>
<td>3.05 - 0.20</td>
<td>3.41</td>
<td>3.55</td>
<td></td>
</tr>
<tr>
<td>Arginine</td>
<td>3.15 - 0.26</td>
<td>4.14</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>7.65 - 0.56</td>
<td>7.41</td>
<td>7.38</td>
<td></td>
</tr>
<tr>
<td>Glycine</td>
<td>1.57 - 0.14</td>
<td>2.08</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>23.40 - 0.78</td>
<td>23.16</td>
<td>20.32</td>
<td></td>
</tr>
<tr>
<td>Histidine</td>
<td>2.51 - 0.20</td>
<td>3.02</td>
<td>4.99</td>
<td></td>
</tr>
<tr>
<td>Isoleucine</td>
<td>6.40 - 0.28</td>
<td>6.60</td>
<td>4.31</td>
<td>15.9</td>
</tr>
<tr>
<td>Leucine</td>
<td>10.44 - 0.52</td>
<td>10.00</td>
<td>9.94</td>
<td></td>
</tr>
<tr>
<td>Lysine</td>
<td>7.58 - 0.28</td>
<td>8.06</td>
<td>8.23</td>
<td>7.2</td>
</tr>
<tr>
<td>Methionine</td>
<td>3.47 - 0.19</td>
<td>3.19</td>
<td>3.54</td>
<td>3.8</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>5.64 - 0.29</td>
<td>5.41</td>
<td>6.00</td>
<td>5.8</td>
</tr>
<tr>
<td>Proline</td>
<td>13.28 - 0.82</td>
<td>11.83</td>
<td>14.59</td>
<td></td>
</tr>
<tr>
<td>Serine</td>
<td>5.88 - 0.26</td>
<td>6.60</td>
<td>5.16</td>
<td></td>
</tr>
<tr>
<td>Threonine</td>
<td>6.31 - 0.19</td>
<td>4.30</td>
<td>5.73</td>
<td>4.1</td>
</tr>
<tr>
<td>Throsine</td>
<td>5.76 - 0.42</td>
<td>5.80</td>
<td>4.77</td>
<td></td>
</tr>
<tr>
<td>Valine</td>
<td>7.40 - 0.35</td>
<td>7.47</td>
<td>5.69</td>
<td>10.5</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>1.72 - 0.15</td>
<td>1.81</td>
<td>2.16</td>
<td></td>
</tr>
</tbody>
</table>

Source: Hoeller and Hassan, 1965

²: Nosier et al., 1977.
Table 2: Compositions of milk from various species

<table>
<thead>
<tr>
<th>Species</th>
<th>Water %</th>
<th>Total solids %</th>
<th>Fat %</th>
<th>Protein %</th>
<th>Lactose %</th>
<th>Ash %</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camel</td>
<td>86.6</td>
<td>13.36</td>
<td>4.33</td>
<td>4.02</td>
<td>4.21</td>
<td>0.79</td>
<td>Mukasa-Mugerwa (1981)</td>
</tr>
<tr>
<td>Buffalo</td>
<td>83.56</td>
<td>16.42</td>
<td>6.85</td>
<td>4.25</td>
<td>5.10</td>
<td>0.828</td>
<td>Shalash (1981)</td>
</tr>
<tr>
<td>Cow</td>
<td>86.2</td>
<td>13.8</td>
<td>4.4</td>
<td>3.8</td>
<td>4.9</td>
<td>0.7</td>
<td>Ensminger (1969)</td>
</tr>
<tr>
<td>Goat</td>
<td>87.0</td>
<td>12.9</td>
<td>4.1</td>
<td>3.7</td>
<td>4.2</td>
<td>0.8</td>
<td>&quot;</td>
</tr>
<tr>
<td>Ewe</td>
<td>82.0</td>
<td>18.0</td>
<td>6.4</td>
<td>5.6</td>
<td>4.7</td>
<td>0.91</td>
<td>&quot;</td>
</tr>
<tr>
<td>Horse</td>
<td>90.1</td>
<td>9.9</td>
<td>1.0</td>
<td>2.6</td>
<td>6.9</td>
<td>0.35</td>
<td>&quot;</td>
</tr>
<tr>
<td>Human Being</td>
<td>88.0</td>
<td>12.0</td>
<td>3.8</td>
<td>1.2</td>
<td>7.0</td>
<td>0.21</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Nutritive value

Camel milk compares favourably with cattle and goat milk but not with that of sheep and buffaloes. It is very rich in Vitamin C (5 mg per 100 ml, according to Leupold, 1968) a vital ingredient when fruits and greens are scarce (Knoess, 1976) and contains 70 calories per 100 gram. It is also high in water and mineral contents (El Amin, 1979). Dahl and Hjort (1976) calculated that 4 kg of camel milk would be needed to satisfy the daily calorie requirement of one adult human being, while a consumption of 1.8 kg would meet his protein needs. It is estimated that 18 - 20 camels are required to meet the needs of a nomadic family throughout the year (Sweet, 1965; Lundholm, 1976), assuming that half the animals are in calf. These estimates were based on the fertility rate of the camel, length of lactation period, daily milk production, and the nutritive value of the milk plus any other sources of food.

Utilization of camel milk

There is some prejudice against the use of camel milk among urban populations because of the unusual flavour, saltish taste and low fat content.

The relatively low fat content, however, means that it is easily digestible as compared to cow and buffalo milk. In some countries dromedary milk is considered to have therapeutic properties. In India it is supposed to cure dropsy, jaundice and pathological conditions of the spleen (Knoess, 1979; Yasin and Wahid, 1957).

Camel milk is mostly consumed in a raw state soon after milking, since it is difficult to keep fresh. Dahl and Hjort (1976) noted that the milk sours very rapidly. The itinerant life of the nomads encourages direct consumption of the product, but it can be conserved by making such products as soft cheese and butter. Mares (1954) noted that surplus milk among the Somali is soured and stored as curd or made into cheese. Other reports
indicate that the milk can be made into tallowy white butter and ghee, Hartley (1979) noted that, in Somalia, customs regarding the handling of camel milk vary in different parts of the country. In some areas it is soured, in others it is sugared and sold at market.

Mares (1959) observed that the Somali herders are not very market conscious, but are willing to sell some milk if there is a market at hand. The Afar of Ethiopia are reluctant to sell the milk (Knoess, 1976). El Amin (1979) stated that camel milk is not commercially exploited in the Sudan. Cole (1975) reported that the Murrah Bedouin do not depend on the sale of their animals or animal products to secure the additional food they may need.

With regard to the utilization of camel colostrum, Mares (1954) observed that it is often consumed by the Somali, who regard it as a laxative. On the other hand, Leese (1927) stated that camel milk colostrum of the first few days after parturition is unfit for human consumption and, curiously enough, is considered dangerous to the calf itself, this being so particularly if the dam is fat or if she has calved during the rains, when good grazing flushes the milk. It is the custom to milk most of it by hand on the ground, leaving only a relatively small quantity for the calf. This seems to be usual throughout the whole camel world with the exception of Australia, where the calf often gets all the milk and no excessive mortality has been reported.
REFERENCES


Dinkler, W. 1896 In Milchzeitung, 26: 461, C.W. Grimm Lehrbuch der Chemie und Physiologie der Milch (1929).


Shalash, M.R. 1982 Vet. Sci., I:1


CAMEL GROWTH AND MILK PRODUCTION IN MARSABIT DISTRICT, NORTHERN KENYA

C.R. Field

Summary

Birth weights of camel calves and growth rates of young camels under both traditional and experimental conditions are presented. The fastest growth rates occur when the calf has access to an adequate maternal milk supply. Slowest growth rates occur in dry seasons when the owner competes with the calf and deprives it of sufficient milk.

The liveweights of adult camels are presented in the form of two growth curves - one for the Gabbra and Rendille camels and the other for the larger Somali breed.

The relationship between body size and liveweight is shown and an equation given.

Graphs are shown of the lactation of five camels. Production declines after the first 10-20 weeks and again after the start of pregnancy. The milk production of the camels examined falls within the limits of published records but tends to be lower than average.

Introduction

The camel became domesticated about 3 000 years ago (Bulliet, 1975). Its subsequent importance to man cannot be overstressed (Knöss, 1977, Leupold, 1968).

It is thought that domestic camels originated in Arabia (Bulliet, 1975) and soon migrated to the Horn of Africa, whence they moved into Kenya, Uganda and Tanzania. They did not spread further south to the Kalahari
or west because of their susceptibility to trypanosomiasis which is transmitted by the tsetse fly itself associated with more humid regions.

Later, camels were taken by the Romans to North Africa, possibly for their games. By this time man had learned to ride these animals and from this origin the use of camels as riding animals spread throughout north Africa.

The dromedary also occurs in other middle eastern countries namely those of the Arabian peninsula, Syria, Iran, Afghanistan, Pakistan, and India. They are found in the southern Soviet Socialist Republics of Turkmenistan, Kazakhstan, Tadzhikistan and Uzbekistan where they are owned by both nomads and collective farms and are used for milk (Heraskov, 1965, Kuliev 1959) and meat production (Kuznetsov and Tretyakov, 1970). They have been imported by Australia and the U.S.A. for draught and pack purposes (Bulliet, 1975).

In Africa camels produce milk, meat, blood, hair and hides (Knoess, 1977), and are also used for riding, draught purposes, the raising and transport of water, ploughing, and as pack animals (Bulliet, 1975).

It has been suggested that the camel entered the Horn of Africa soon after it was domesticated but before man had learned to ride it (Bulliet, 1975). This may account for the lack of interest among nomads in Somalia, Southern Ethiopia and East Africa in riding the camel, while in the Danakil desert, some 400 km to the north, camels are ridden by the Afars, no doubt through the expansion of the north African camel riding culture.

Camels in Kenya and other parts of East Africa are used for milk, meat, blood, hides and the transport of water and houses (Bremaud, 1969, Torry, 1973). Perhaps because of the pastoral rather than the agricultural nature of the East African camel cultures, camels are not used for ploughing or irrigation. Since camels have
a greater ability to withstand drought conditions and to produce when other livestock cannot, they are considered to be the most important livestock species of the desert nomadic pastoralists. This is true of the Gabbra and Rendille of Marsabit District, northern Kenya (Torry, 1973; Sato, 1976) as well as of the Somalis of northeast Kenya. Although the Turkana and some Samburu and Pokot keep camels they are relatively recent acquisitions and are not considered to be as important as they are to the Rendille, Gabbra and Somali people. Indeed much of the culture of these three tribes revolves around the camel (Torry, 1973; Grum, 1976) and two to three times a year the Rendille and Gabbra assemble all their camels to be blessed at a special ceremony called the 'Sorii' which is similar in many ways to the Biblical passover ceremony (Exodus, Chapter 12).

In 1976 the Integrated Project in Arid Lands (IPAL) was conceived in the Marsabit district of northern Kenya to determine the factors causing desert encroachment and to demonstrate how degraded land can be rehabilitated. This was in direct response to the Sahelian drought of the early and mid nineteen seventies which had caused considerable loss of human lives and livestock (Glantz, 1976). Clearly, the interactions between livestock and the vegetation are basic dynamic components in the processes of desert encroachment and rehabilitation. Similarly it is desirable to know what the people obtain from their livestock and how many animals they need to fulfil their food requirements.

In order to answer some of these questions, studies have been made by IPAL on camel and small stock ecology (Field, C.R., 1978, 1979; Field, A.C., 1978). The aim has been to investigate the way in which camels use the environment and to determine what role they play in desert encroachment. Studies have also attempted to assess the importance of camels to the people with regard to the production of food and their use for transport purposes.
The two basic production factors of camels are growth and milk production. Blood is mentioned only in passing as it has not been possible to measure a scientifically valid sample for our purposes.

Camel productivity

(a) Growth

(i) Materials and Methods

IPAL purchased nine camels from Rendille and Gabbra nomads. They consisted of one male, three castrates and five female camels. A further six camels consisting of three cows and their attendant calves were loaned to the Project. Since the formation of the herd, seven calves have been born to date (October 1979), three females and four males. One of the latter died at birth. One of the castrates was destroyed leaving a herd of 20 animals.

New-born camels were weighed when dry and within twelve hours of birth. Calves were weighed subsequently at key intervals in a sling suspended from a scale and chain hoist until a weight of 260 kg was reached. Older animals were trained to walk on to an hydraulically operated platform scale (Donald's Presses, Christchurch, New Zealand). Because of weight loss when penned at night the animals are usually weighed in the evening and morning at the end and start of a day's feeding respectively.

Three body measurements were recorded at the time of weighing:

1. Shoulder height in a straight line from ground to top of scapula;

2. Heart girth around the curve just behind the sternal pad;
3. hump girth along the curve over the mid-point of the hump and abdomen.

Rendille and Gabbra camel calves were weighed using a sling and chain hoist as for the project animals. They were aged by questioning the owner and checking the stage of tooth eruption.

(ii) Results

Birth weights

Seven new-born camel calves have been weighed. One of these, a male, died during parturition, but there is no evidence that it was abnormal and it is included here. Overall mean weight at birth was 30.9± 4.3 kg; range 23.5 to 36.4 kg. Mean weight of male calves was 28± 3 kg while mean weight of females was 34.8 ± 1.4 kg. Numbers are small and it is not yet clear whether there is a significant difference in birth weights between sexes.

Growth

Weights of the nine calves available to the project have been placed in three groups. The first group includes two camels, Nos. 12 and 13, which exhibited the fastest growth rate. The equivalent liveweight gains are shown in Table 1. Group 2 is comprised of three calves, Nos. 17, 18, and 19, whose mothers are of the Somali breed. They were loaned to the project when they were approximately one month old. Group 3 consists of four calves, Nos. 10, 11, 20, and 21, whose rate of growth was slower for the following reasons. Numbers 10 and 21 had the same mother, an old female. Number 11 contracted a disease at four months of age which caused a growth check lasting six weeks, while the mother of number 20 failed to produce milk and the calf was fed several times a day with camel milk by hand. The growth curves of these three groups are shown in graphic form in Figure 1.
Mean rate of growth for the first year for Group 1 was 0.58 kg\(\text{d}^{-1}\) year\(^{-1}\) while it was only 0.44 kg\(\text{d}^{-1}\) year\(^{-1}\) for Group 3 animals.

Over three hundred Rendille, Gabbra and Turkana young camels have been weighed, sexed and aged at the following places: Kargi, Ngorunit, Balesa, Lonip, Gus, Did Siribi, North Horr, Kalacha and Maikona.

Data for the Rendille, Gabbra and Turkana owned camels are presented in Figure 2 and Table 2.

The Years 1969 to 1976 had below average rainfall while that of 1977 to the first half of 1979 was above average. Therefore, where sufficient data are available camels are grouped according to the period in which they were born and grew.

From the curves it can be seen that the rates of growth of both Rendille and Gabbra camels are faster in wet years than in dry years. This amounts to a difference at six months of age of approximately 10 kg in Rendille camels and 20 kg in Gabbra camels. At one year of age Gabbra camels born in dry years were approximately 26 kg lighter than those born in wet years and 62 kg lighter than Turkana camels born in wet years.

Birth weights are not known, but if they are assumed to be similar to those of the seven IPAL calves, then the liveweight gains were as shown in Table 2.

Mean rates of growth during the first year for Gabbra, Rendille and Turkana camels were 0.19, 0.23 and 0.31 kg\(\text{d}^{-1}\), respectively. In dry years mean rate of growth for the first year for Gabbra camels was 0.14 kg\(\text{d}^{-1}\) while Rendille camels over the first nine months was 0.27 kg\(\text{d}^{-1}\).

Growth of camels up to seven years of age has been studied in the Project herd, ageing of camels between five and seven years being possible through the sequence
of eruption of the permanent incisors (Williamson and Payne, 1965). Above seven years of age the molars are used for ageing purposes and these are difficult to examine in the living animal, hence the shape of the growth curves are currently somewhat hypothetical above the age of seven years. Considerable individual variation occurs depending on weighing in the evening or morning, whether the animal has just watered and the stage of pregnancy of the animal. Figure 3 shows the hypothetical growth curves of Somali and Rendille/Gabbra type animals. From the curves it can be seen that maximum weights for females are obtained between 12 and 15 years and are of the order of 720 kg for Somali type camels and 550 kg for Rendille/Gabbra type camels. There is a substantial weight loss in old camels amounting to about 150 kg in Rendille and Gabbra camels aged twenty or over, and more than 200 kg in Somali type camels.

To demonstrate the relationship between body dimensions and weight, the sum of the heart girth, hump girth and shoulder height of camels has been plotted against liveweight: the results are presented in Figure 4.

Although there is a gap in the size range 515 to 595 cm a close relationship clearly exists between weight and body size following a typical power curve at least to 650 cm which is expressed as follows:

\[ y = 6.46 \times 10^{-7} x^{3.17} \]

where \( y \) = liveweight in kg
\( x \) = sum of the three measurements in cm.
The correlation coefficient \( r^2 = 0.99 \)

Discussion

The growth and production of meat in the dromedary has been reported on extensively in the Soviet Union
(Lakoza, 1962; Blagovescenskii, 1963; Aueljbekov, 1967; Kuznetsov and Tret'yakov, 1970; Keikin, 1976). These authors give weights at age as follows:

3 months 79.6 kg
15 months 310.0 kg

They note that the bactrian camel is heavier and that there appears to be hybrid vigour in the offspring of female bactrian camels crossed with male dromedaries, but not the reverse.

Birth weights for a large sample of Indian Bikaner calves averaged 38.3 kg for males and 37.3 for females, the difference being non-significant (Bhargava, Sharma and Singh, 1965). Birth weights of 35 to 40 kg have been reported for Soviet camels (Aueljbekov, 1967).

In Somalia, Congiu (1953) recorded an average live-weight for 50 male camels of 554 kg and for 100 female camels of 514 kg. Dressing percentages were 56 and 54 percent respectively. Other figures of camel carcass yield are given by Wilson (1978) for the Sudan, and by Bremaud (1969) for northeastern Kenya.

Some general data on camel growth and meat production are available from Knoess (1976, 1977) and Fazil (1977).

It appears that birthweights of project camels are lower than those of Indian and Soviet camels by about 7 kg although the raw data of Bhargava et al. (1965) and Aueljbekov (1967) are not available for statistical comparison. The lower birthweights of Rendille and Gabbra camel calves is in accordance with their generally smaller size as compared to Indian and Russian dromedaries.

Growth rates of young camels up to 12 months in the IPAL study area are highly variable ranging from 0.58 to 0.58 kg d^{-1} yr^{-1} for the best project animals, to 0.14 kg d^{-1} for Gabbra camels in drought conditions. Within the
Gabbra/Rendille breed, the fastest rates appear to be dependant on a good maternal milk supply and the absence of recognizable disease.

Of these two factors the milk supply is of primary importance since a well fed calf will be more able to resist disease than a malnourished animal. In this respect it has been noticed that the colostrum, which is known to be rich in antibodies, is often considered bad for the calf by the unwitting pastoralist and may only be permitted in small quantities.

The overall faster growth rates of the IPAL calves (from 0.44 to 0.58 kg d\(^{-1}\) yr\(^{-1}\)) compared with the camels of nomads (0.19 to 0.31 kg d\(^{-1}\) yr\(^{-1}\)) can be attributed to the different management regime of the project camels which leads to a greater proportion of the mother's milk reaching the calf than the owner. This regime involves the separation of the calf from its mother during the night period for about two hours in the case of a very young calf to twelve hours in a two month old calf, and permitting the calf to accompany the dam and suck during the daytime. Since the owner milks only half the udder while the calf is allowed the remainder the proportion of milk received by the calf ranges from 96 percent in young project calves to 75 percent in older project calves, down to 50 percent or less in calves belonging to nomads. An additional advantage of the project's system is that the calf soon experiences good grazing and can learn from its mother to select the most palatable food plants, while under the traditional system calves cannot graze in the company of their mothers until lactation ceases, perhaps after a year. (Plates 1 and 2)

The effect of a reduced milk supply can be seen even in the project herd where camels 10 and 17 to 21 had a sub-optimal milk supply. This was because of dry conditions which led to a lower maternal milk production in the case of camels 17 to 19; an old mother having reduced output in the case of camels 10 and 21 and sickness in the calf (No. 11) and mother (No. 20).
However, growth was still better than any indigenous calves, which further stresses the competitive nature of man's relationship to the calf and emphasizes the importance of having an adequate milk supply. This has been referred to previously (Bremaud, 1969). It is not clear why tribal differences in the growth rates of calves appear to exist. The high rate of growth of Turkana camels may be partly attributed to the small sample size \( n = 17 \) involved.

It is relevant here to note that all project animals were heavier and all indigenous camels lighter at three months than Soviet camels. However, all were substantially lighter than Soviet camels at fifteen months.

There are numerous references in the literature to adult camel weights. These are summarized as follows:

<table>
<thead>
<tr>
<th>Locality</th>
<th>Weight in kg.</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>453.6-557.9</td>
<td>Leese (1927)</td>
</tr>
<tr>
<td>Sudan Kababish</td>
<td>450</td>
<td>Mason and Maule (1960)</td>
</tr>
<tr>
<td>Somalia Benadir</td>
<td>554</td>
<td>Congiu (1953)</td>
</tr>
<tr>
<td>Somalia Benadir</td>
<td>514</td>
<td></td>
</tr>
<tr>
<td>Somalia north</td>
<td>350-400</td>
<td>Mason and Maule (1960)</td>
</tr>
<tr>
<td>Ethiopia Afar</td>
<td>455</td>
<td>Knoess (1976)</td>
</tr>
<tr>
<td>Ethiopia Afar</td>
<td>350-400</td>
<td>Knoess (1976)</td>
</tr>
<tr>
<td>Ethiopia Afar</td>
<td>318-400</td>
<td>Knoess (1976)</td>
</tr>
<tr>
<td>Russia, Astrakhan</td>
<td>455-850</td>
<td>Terentjiev (1966)</td>
</tr>
<tr>
<td>Russia, Astrakhan</td>
<td>651-970</td>
<td>Terentjiev (1966)</td>
</tr>
</tbody>
</table>

Adult female camels in the project herd lie in the range 400 - 720 kg the latter being a Somali type camel. Weights are highly variable with season, substantial losses being sustained during drought periods. Males and castrates range from 420 - 630 kg, the latter being a Somali type camel. Thus two growth curves have been drawn, one for Gabbra/Rendille type camels which, when fully grown and in good conditions, range from 450 to
550 kg between the ages of eight and eighteen; and one for Somali type camels which range from 550 to 720 kg between the ages of eleven and seventeen (Figure 3). The former follow closely Leese's (1927) average weights and fall within the range of the Sudanese camels, Somali Benadir female and Afar males. Drought conditions could reduce the minimum weight to 350 kg which would be less than all but the Ethiopian and north Somali camels. The Somali type camels are more similar to the larger Russian breeds.

(b) Milk production

(i) Materials and methods

The lactations of eight female camels in the IPAL herd have been studied in detail. Three lactations have been followed for their complete duration although the calf of one of the females died at birth. Four camels are still lactating while in a fifth the second lactation is being observed.

Calves are separated from their mothers for a variable but known period of time at night. On returning the calf to the mother two teats are milked while the other half of the udder is suckled. The quantity of milk collected is measured and expressed on a twenty-four hour total udder basis. In the case of the camel whose calf died the whole udder was milked twice a day.

(ii) Results

Results from five lactations are illustrated in figures 5, 6, and 7. Daily estimates of milk production have been summarized on a weekly basis for four Rendille/Gabbra type camels. Two lactations are illustrated for camel No. 5.

With the exception of camel No. 6 which lost its calf at birth all three other animals showed high levels of production during the first ten to twenty weeks after
parturition. There was considerable fluctuation in estimated amounts as follows:

Estimated production in litres per day

<table>
<thead>
<tr>
<th>Camel No.</th>
<th>Birth to 20 weeks</th>
<th>21 to end lactation or 60 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 First lactation</td>
<td>3.8 - 10.5</td>
<td>1.3 - 5.1</td>
</tr>
<tr>
<td>5 Second lactation</td>
<td>2.8 - 17.0</td>
<td>N.R.</td>
</tr>
<tr>
<td>6 Calf lost</td>
<td>1.8 - 3.7</td>
<td>0.2 - 4.2</td>
</tr>
<tr>
<td>7</td>
<td>4.5 - 50.2</td>
<td>2.2 - 6.2</td>
</tr>
<tr>
<td>9</td>
<td>4.9 - 10.0</td>
<td>0.7 - 4.7</td>
</tr>
</tbody>
</table>

N.R. = No Record

It is possible that the high yields from No. 7 in the first four weeks are due to the very short separation time of the calf and these figures may be anomalous. Thus mean daily yields in the first 20 weeks (5 months) range from a minimum of 2.8 litres to 17 litres, while in the remaining months they range from 0.7 to 6.2 litres. The camel which had no calf and therefore lacked the normal stimuli, showed lower levels of production reaching a peak between the 24th and 31st week. Mating of this animal occurred in the 30th, 31st and 34th week after parturition and there was a marked decline in milk production after this. The first major fall in production by camel No. 9 came in the fourteenth week of lactation some six weeks after estimated pregnancy. In contrast to this camel, No. 5 showed a decline from about 4 l/d\textsuperscript{-1} to < 2 l/d\textsuperscript{-1} around the 44th week of lactation which is the estimated date of pregnancy.

Duration of lactation averages 55 weeks (n = 4) but one female (No. 7) continued to lactate 74 weeks after calving. It appears that this animal was mated but failed to become pregnant.
Total estimated milk production was as follows:

Camel
5  1 875.49 litres
6  1 019.36 litres
9
7  (continuing)

(iii) Discussion

There have been several studies of camel milk production in the Soviet Union (Heraskov, 1953, 1965; Kuliev, 1959), Pakistan (Yasin and Wahid, 1957), Ethiopia (Knoess, 1977), and Kenya (Sato, 1976; Torry, 1973; Bremaud, 1969). These and others are summarized below.

It is not always clear from the literature (e.g. Sato, 1976; Torry, 1973) whether the author is referring to the estimated total milk production or just that available to the owner. The former appears to be likely in most cases except those indicated with an asterisk which are from anthropological and socio-ecological studies where the emphasis has been on the food available for human consumption.

In some cases also, it is not clear whether the author has calculated a mean daily production over the whole period of lactation or whether data are used from the first few months of lactation, or from optimum conditions (e.g. Bremaud, 1969; Knoess, 1976).
Camel milk production

<table>
<thead>
<tr>
<th>Place</th>
<th>Daily litres</th>
<th>Total litres</th>
<th>Duration (m=months d=days)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>USSR Kazakhstan</td>
<td>2-6.9</td>
<td>709-2621</td>
<td>7-18 m</td>
<td>Herashkov, 1965</td>
</tr>
<tr>
<td>USSR Turkmenistan</td>
<td>4.2-5.9</td>
<td>2000-3000</td>
<td>480-510 d</td>
<td>Kuliev, 1959</td>
</tr>
<tr>
<td>Pakistan</td>
<td>9.1-13.6</td>
<td>-</td>
<td>-</td>
<td>Yasin and Wahid, 1957</td>
</tr>
<tr>
<td></td>
<td>- 9.1</td>
<td>-2728</td>
<td>9 - 18 m</td>
<td>Williamson and Payne, 1965</td>
</tr>
<tr>
<td>Pakistan</td>
<td>-</td>
<td>1350-3600</td>
<td>270-540 d</td>
<td>Knoess, 1976</td>
</tr>
<tr>
<td>Pakistan</td>
<td>1700-3000</td>
<td>270-540 d</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Ethiopia Adal</td>
<td>-</td>
<td>2442 (1200-3700)</td>
<td>365 d</td>
<td>&quot;</td>
</tr>
<tr>
<td>Ethiopia Eritrea</td>
<td>5 - 6</td>
<td>-</td>
<td>-</td>
<td>Mason and Maule, 1960</td>
</tr>
<tr>
<td>Kenya, Marsabit</td>
<td>10</td>
<td>-</td>
<td>10-24 m</td>
<td>Bremaud, 1969</td>
</tr>
<tr>
<td>&quot; , Mandera</td>
<td>9</td>
<td>-</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot; , Wajir</td>
<td>12</td>
<td>-</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot; , Tupcha Rendille</td>
<td>1.3</td>
<td>-</td>
<td>20 m</td>
<td>Sato, 1976</td>
</tr>
<tr>
<td>&quot; , Gabbra Odola/Galbo</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td>Torry, 1973</td>
</tr>
<tr>
<td>Kenya, Marsabit</td>
<td>2.7-4.0</td>
<td>1019-1975</td>
<td>385 d</td>
<td>This study</td>
</tr>
<tr>
<td>&quot; , Rendille</td>
<td>3.8</td>
<td>-</td>
<td>12 m</td>
<td>Spencer, 1973</td>
</tr>
<tr>
<td>East African</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>Morgan, 1972</td>
</tr>
<tr>
<td>Somalia</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>Rosseti and Congiu, 1955</td>
</tr>
<tr>
<td>N. African Tuareg</td>
<td>0.1-10</td>
<td>-</td>
<td>-</td>
<td>Nicolaisen, 1962</td>
</tr>
<tr>
<td>Sahara</td>
<td>1.9-4</td>
<td>-</td>
<td>-</td>
<td>Capot-Rey, 1962</td>
</tr>
<tr>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>9-18 m</td>
<td>Leese, 1927</td>
</tr>
<tr>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>9-18 m</td>
<td>Leupold, 1968</td>
</tr>
<tr>
<td>N. Arabia Bedouin</td>
<td>1.7</td>
<td>-</td>
<td>-</td>
<td>Musil, 1928</td>
</tr>
</tbody>
</table>

Nevertheless, the mean daily production by the four IPAL camels lies within the limits of the data available in the literature although it is substantially lower than that of Pakistan camels (Yasin and Wahid, 1957) and is less than half the daily production in Northern Kenya under optimum conditions (Bremaud, 1969).

The total amount of milk produced and the duration
of lactation also lie within the limits of the data quoted in the literature. The lower figure quoted for total amount produced in a lactation came from the cow which had no calf. This animal also had the lowest daily production of milk.

Conclusions

The measurement of the rates of growth of young camels under varying forms of management indicates that it is possible to achieve much faster rates of growth than is normally found under traditional pastoralism. The fact that the slowest growth rates occur under the traditional system during dry conditions and the fastest when calves are allowed a longer period of access to suck their mothers and there is abundant grazing indicates that the amount of milk permitted for the calf is of fundamental importance in controlling the rate of growth.

Clearly a camel owner may not be able to afford allowing the calf to suck to the degree permitted in the IPAL herd. However, these findings may be of more than just academic importance, since it is observed that camels which are stunted do not show compensatory growth (see Group 3 in Figure 1). It remains to be seen whether they are permanently stunted at maturity or whether sexual maturity is delayed until a certain body size is reached, but the evidence from other mammalian studies is that the latter is unlikely. If permanent stunting is the case (camel No. 6 appears to be an example of this) then it is likely that such animals will be poor milk producers and the owner will have lost in the long term. Furthermore mating of stunted females with fully grown males may lead to problems with calving and the loss of young.

It is known that the Rwala Bedouin kill male calves so that more milk is left for human consumption (Musil,
1928). Such a practice might be worthy of consideration in other areas keeping only sufficient males for breeding, transport and bleeding purposes.

The evidence presented on milk production indicates that the animals under study are lactating within the range of known information but that production tends to be near the lower limit. Total camel milk production generally is in excess of that of cattle per lactation (Dahl and Hjort, 1976) although of course this is because cattle lactate for a shorter period of time. Thus camels provide a protracted but rather small supply of milk for the nomads. Their ability to continue lactation under the most adverse drought conditions when all other livestock have ceased is a major reason for the nomad in arid areas favouring them above all other livestock.

Table 1: Rates of growth in Kgd\(^{-1}\) for three groups of camel calves

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth - 1 month</td>
<td>0.95</td>
<td>-</td>
<td>0.53</td>
</tr>
<tr>
<td>1 month - 3 months</td>
<td>0.63</td>
<td>0.76</td>
<td>0.61</td>
</tr>
<tr>
<td>3 months - 6 months</td>
<td>0.54</td>
<td>0.14</td>
<td>0.16</td>
</tr>
<tr>
<td>6 months - 9 months</td>
<td>0.70</td>
<td>-</td>
<td>0.56</td>
</tr>
<tr>
<td>9 months - 1 year</td>
<td>0.36</td>
<td>-</td>
<td>0.48</td>
</tr>
<tr>
<td>1 year - 15 months</td>
<td>0.20</td>
<td>-</td>
<td>0.09</td>
</tr>
<tr>
<td>15 months - 18 months</td>
<td>-</td>
<td>-</td>
<td>0.37</td>
</tr>
<tr>
<td>18 months - 21 months</td>
<td>-</td>
<td>-</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Table 2: Rates of growth in Kgd\(^{-1}\) for Rendille, Gabbra and Turkana

<table>
<thead>
<tr>
<th></th>
<th>Wet years</th>
<th>Dry years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gabbra</td>
<td>Rendille</td>
</tr>
<tr>
<td>Birth - 1 month</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 month - 3 months</td>
<td>0.31</td>
<td>0.27</td>
</tr>
<tr>
<td>3 months - 6 months</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6 months - 9 months</td>
<td>0.12</td>
<td>-</td>
</tr>
<tr>
<td>9 months - 1 year</td>
<td>0.06</td>
<td>0.21</td>
</tr>
<tr>
<td>1 year - 15 months</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15 months - 18 months</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18 months - 21 months</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>21 months - 24 months</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 1: Growth curves of IPAL camel calves

Figure 2: Growth curves of Rendille, Gabbra and Turkana camels
Figure 3: Hypothetical growth curves of camels

Figure 4: Camel size/weight relationships
Figure 5: Estimated milk production from two camels

Figure 6: Estimated milk production from camel no. 9

Figure 7: Estimated milk production from two camels. Subsequent lactation of camel no. 5
REFERENCES


Congiu, S. 1953 Particulars on the dressed carcase, far distributions and correlations between the weights of the different organs of the Somali dromedary. Zootec. Vet. 8:188-191


Knoess, K.H. 1977 The camel as a meat and milk animal. World Animal Rev. 22:3-8


Plate 1: Four day old calf sucking. In 305 days the dam yielded about 6,000 litres of milk. (Photo K.H. Knoess)

Plate 2: Four day old calf sucking. In 305 days the dam yielded about 6,000 litres of milk. (Photo K.H. Knoess)
THE PRODUCTION AND UTILIZATION OF CAMEL MEAT

by M.R. Shalash

Introduction

There is a growing awareness of the food shortage which is facing the world. It is estimated that about 25 percent of the world's human population is hungry or malnourished and that one human being in eight suffers from debilitating malnutrition. In the economic order of the world food strategy is now receiving the highest priority. It calls for consideration of all means of production, with cost minimization.

The role of the camel in the modern world is changing as pastoral societies evolve or decline, and the traditional use of the camel primarily as a transport animal is diminishing. Camels, however, continue to be an important component of an ecosystem in which the flora of marginal land can be converted to human food. Due to the specialized morphology and the unique dexterity of the mouth parts, the camel can browse upper storey plants. Its preferred diet is largely ignored by other animals, and camels can therefore contribute substantially to the solution of food problems in many arid and semi-arid areas, where hunger and malnutrition are prevalent.

The production potential of the species, and the manifold purposes which it may serve, combined with its ability to perform efficiently in harsh environments, are compelling reasons for investigating the systematic exploitation of this important animal resource. Relatively few data are available on camel productivity. The present review is based on the limited information on meat production potential including growth rate, birth weight, the nutritive value of different components, the value of the camel fat depot, the digestion coefficient and the use of camel meat in preparing manufactured products.
Growth rate

Heredity is a factor affecting prenatal growth, directly via the genotype of the foetus and indirectly through the genotype of the dam. The exact role of this factor in the camel has not been investigated.

The nutritional status of the dam may also have a direct bearing on foetal growth, a factor which would seem to be important in the camel. Poor nutritional levels during gestation may lead to prenatal mortality. Musa (1979), who studied the development of the camel foetus and its associated growth curve, concluded that there was a striking similarity to the pattern for cattle.

Bhargava et al (1965) in a study which involved 134 camel records over a 3-year period, reported that the sex of the calf, the calving sequences and the month of calving apparently had no statistically significant effect on birth weight. They found that the smallest calf weighed 26.3 kg, half the weight of the heaviest calf, which was 52.15 kg. The average birth weight for males was 38.19 kg and for females 37.19 kg, with a pooled average of 37.23 kg.

Burgemeister (1975) found that birth weights of Tunisian camel calves (25.81 ± 2.14 kg) were lower than the average weights for the Indian dromedary (37.23 kg) and the Rendille and Gabbra calves in Kenya (30.9 kg) recorded by Field (1979). Burgemeister (1975) further recorded that the shoulder height of the calves (95.4 ± 2.34 cm) was greater than the 75 cm estimated by Leonard (1894) for the Arabian camel. Such differences reveal the variations in camel calf performance attributable to breed, strain, environment and management. Burgemeister (1975) studied the postnatal growth performance of young dromedaries at weekly intervals. The results showed that male calves tend to grow faster than female ones. Field (1979) studied the growth patterns in two groups of camel calves in northern Kenya; one under pastoral conditions and the other under special experi-
mental conditions whereby the young received at least 75 percent of the dam's milk. The former group showed average daily gains of 222 gm to 255 gm during the dry and wet seasons, while gains ranged from 378 gm to 655 gm for the latter group. These figures reflect the important influence of milk on growth and indicate the negative effects of competition for milk between calf and man under the pastoral management system. The results also showed a better performance by calves born during the wet season, irrespective of the breed.

Although Williamson and Payne (1978) reported that the lactation period of the camel may last up to 2 years, the suckling young are generally weaned at any time between 3 and 18 months under traditional pastoral systems, the average being 12 months. Camel calves start to graze when they are only a few weeks old, the change from milk to more solid food occurring gradually and with no adverse effect on growth. Field (1979), on the other hand, observed in one case that the live weight gain dropped from preweaning level of 410 gm per day to 317 gm per day during the 6-month period after weaning.

Dong Wei (1979) reported that, although the Chinese bactrian camel grows and develops slower than other domestic animals, it grows very rapidly in the first year. The heart girth, which is only about 60 percent of the height at birth exceeds the latter as early as the sixth month. From the second year of life the growth rate becomes progressively slower.

Body liveweight and dressing percentage

Camel meat is relished by desert nomads. In certain areas it replaces beef and mutton although it is not considered to be as palatable. It is an important source of animal protein. The fat depot in the hump provides the principal cooking medium.

Mason and Maule (1960) estimated that the average
liveweight of the kababish baggage camel in eastern and southern Africa was 450 kg, while that of the Somali camel was 350 to 400 kg. Ahmediev and Pravendnev (1964) reviewing the productivity of the bactrian camel, stated that 260 - 500 kg of meat can be obtained per animal. Kulaeva (1964) also found that the dressing percentage varied from 56 to 70 percent and stated that camel meat resembles beef in taste. Bremaud (1969) reported an average liveweight of 450 kg for Somali camels of northern Kenya. Pratt and Gwynne (1977) estimated the average weight of the East African camel to be 400 kg, although mature males and females could attain weights of 500 to 550 kg, with a height of just over 2 metres. Dina and Klintegerg (1977) reported that the average liveweights of Somali camels in Ogaden region was calculated to be for males 554 kg and 309 kg for females. Height at the withers varied from 165 to 215 cm. However, recent data are consistent with the range of 453.5 - 557.9 kg reported earlier by Leese (1927).

Shalash and his colleagues (1978) found that the quantity of meat obtained from camels varies with age, sex and nutrition, the range being from 125 kg to 480 kg, while the dressing percentage varied from 55 to 70 percent. Williamson and Payne (1978) reported dromedary weight as ranging from 454 to 590 kg, while bactrian camels were somewhat heavier. Dong Wei (1979) stated that the economic importance of the Chinese bactrian camel is primarily in work output and wool production. However, it was found that body weight ranged from 400 to 800 kg and dressing percentage varied between 35 and 52 percent. Knoess (1976) observed that the liveweight of mature Afar camels in the Awash valley of Ethiopia rarely reached 500 kg. The wither height was calculated as 1.75 metres and the heart girth and abdominal circumference of three males averaged 1.85 and 2.12 metres respectively.

Wilson (1978) reported that the shoulder height of Darfur camels in southern Sudan ranged from 180 to 200 cm in females. He also noted that girth circumference
was not a reliable indicator of individual weights, although it gave a fair estimate of group averages. Field (1979), on the other hand, demonstrated a very high correlation between three body measurements of shoulder weight, heart girth and hump girth. The sum of these could be used to predict body weight, using a regression equation.

It seems that there is a considerable phenotypic variation in the liveweight of mature dromedaries whose age at full growth ranges from 6 to 7 years for males and from 7 to 8 years for females. Khatami (1970), on the basis of feeding experiments, found the daily weight gain for females to be 0.95 kg and 1.4 kg for males. He also found that the carcass weight of the Iranian dromedary was 300-400 kg. Bremaud (1969) noted that camel appendages (femoro-tibial and humero-radial joints) could weigh 44 kg, yielding 22-26 kg of meat. On the other hand Wilson (1978), in a slaughter house study involving 60 camels, found that the average liveweight of Darfur camels was 426.2 kg while the carcass weight was 208.5 kg, showing a dressing percentage of almost 49 percent. Males generally have a higher dressing percentage than females. However, Dahl and Hjort (1976) demonstrated that the dromedary has a higher dressing percentage than pastoral cattle. Further investigations are needed to ascertain if the dromedary can sustain such high percentages under all management and ecological systems.

Wilson (1978) estimated that the amount of blood and fluids at slaughter is equivalent to 9.1 percent of the carcass weight. With Sudanese camels the blood and fluid losses ranged from 31 to 53 kg for 14 mature males, but there is no indication as to how much blood could be recovered at slaughter.

Some nomads consume the blood of camels and Pratt and Gwynne (1977) found that Turkana camels can yield 5.5 litres per bleeding and may be bled twice a month.
Meat quality and nutrient components

Leupold (1968) described camel meat as palatable, coarser than beef, varying in colour from raspberry-red to brown-red and having white fat. The glycogen content is high and, like horse meat, camel meat has a sweetish taste. Khatami (1970) reported that in appearance, colour, texture and palatability camel meat closely resembles beef, adding that the carcase of a well-fed camel is covered by a thin layer of fat. Most pastoralists prefer the meat of young camels 4 to 6 months old, as it is similar in taste and texture to beef (Leupold, 1968; Fischer, 1975; Dahl and Hjort, 1976; Knoess, 1977; Chatty, 1972).

El Amin (1979) stated that camels mature comparatively slowly. Dahl and Hjort (1976) reported that camels can be slaughtered for human consumption at any time between 4 and 10 years of age. With increasing age thereafter the meat becomes tougher, less tasty and of inferior quality. Dina and Klinteberg (1977) recommended slaughtering camels at 2.5 to 3 years of age with an average weight of 300 kg; the animal is then not fully grown and the meat is tender.

Meat differs in composition according to type and condition and the fat content of tissues varies greatly (Bailey, 1951). The chemical composition of camel meat has been studied by Abdel Baki (1957), Hammam et al (1962) and Nasr et el (1965) and the results indicate that the meat of young camels, i.e. less than 5 years of age, has a higher moisture content (78.27 percent) than that of older animals (76.24 percent). The protein, crude fat and ash content of the two age groups were estimated as 20.07 and 22 percent, 0.92 and 1.01 percent, and 0.76 and 0.86 percent respectively, with no significant difference between the sexes. Considering the variations of the different main components found in the different cuts examined (sternum, shoulder, thigh, longissimus and round), no marked difference could be detected between males and females of the same age, except in the crude fat content of aged animals, where the fat content was comparatively
higher in the sternum of the females than in that of the males; the fat depot in the thigh is nearly always lower than that in the sternum or shoulder, so it can be concluded that little marbling is associated with camel meat.

Comparing the composition of camel meat with various animal types (Hisashi, 1961), it is evident that meat from camels below 5 years of age has almost the same percentage of crude protein as that of the steer, while meat from camels of 5 years old or over contains a higher percentage of crude protein than that of the bull, cow and steer. On the other hand, the crude fat and ash content of camel meat are comparatively lower than that of beef (Nasr et al, 1965)

Table 1: Mean values of different meat components in bulls, cows, steers and camels.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Water %</th>
<th>Protein %</th>
<th>Fat %</th>
<th>Ash %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull</td>
<td>76.41</td>
<td>20.95</td>
<td>1.20</td>
<td>1.05</td>
</tr>
<tr>
<td>Cow</td>
<td>75.52</td>
<td>21.19</td>
<td>3.99</td>
<td>1.02</td>
</tr>
<tr>
<td>Steer</td>
<td>72.98</td>
<td>20.41</td>
<td>4.88</td>
<td>0.97</td>
</tr>
<tr>
<td>Camel, 5 years or more</td>
<td>76.24</td>
<td>22.02</td>
<td>1.01</td>
<td>0.86</td>
</tr>
<tr>
<td>Camel, under 5 years</td>
<td>78.27</td>
<td>20.07</td>
<td>0.92</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Source: Nasr et al (1965)

Abdel Baki et al (1957) observed that camel meat after 9 days of cold storage became slightly darker due to oxidation of the hemoglobin. The results indicate that total protein and total fat remain nearly constant. The soluble protein increased during cold storage, while coagulable protein decreased. The alkali insoluble protein decreased gradually during the cold storage period. The lactic acid content increased and the pH value of the meat decreased. The rancidity of the fat content as measured by the increase in the acid value and peroxide value showed a slight increase and the iodine number decreased gradually during cold storage.
Camel meat is often said to be one of the toughest of meats and it was of interest to test the tenderness of different cuts. Abdel Baki et al (1957) found that the location of the cut determines to a great extent the tenderness of the meat. The alkali insoluble protein of the round cut was nearly twice that of the tenderloin. In other words, the amount of alkali insoluble protein, the shearing value and the diameter of the fibres were inversely proportional to the tenderness of the meat. The number of fibres was directly proportional to the tenderness (Table 2).

In spite of the indications of the high quality of meat from young camels, there is a great reluctance on the part of camel owners to sell their young stock. Most trade, therefore, consists of meat from much older camels, the low quality of which has a direct bearing on the extent of demand for camel meat outside the camel herding societies. In this respect, Bremaud (1969) observed that the average age of 26 animals sold for slaughter in the Wajir market in north Kenya was 14.5 years. It is, therefore, hardly surprising that camel meat is often considered inferior by urban societies, and is sold cheaply (Cole, 1975). Nevertheless, evidence is accumulating which indicates that when quality standards are set and adhered to, camel meat can be successfully marketed alongside that of cattle, sheep and goats (Mukasa-Mugerwa, 1981).

Camel depot fat

The fat derived from the camel is of very great nutritional importance in meeting the need for fat in the human diet. Throughout Arabia the hump of camels slaughtered or dead from whatever cause is rendered to provide grease (Leese, 1927). The edible fats of the camel are obtained from the hump, the mesentery and the perinephric area. Armstrong and Allan (1924) recognized the major component acids, palmitic (37 percent), stearic (16 percent) and oleic (47 percent). Later,
Table 2: Examination of camel meat tenderness.

<table>
<thead>
<tr>
<th>Meat cut</th>
<th>Alkali insoluble protein</th>
<th>Shearing value</th>
<th>Diameter of fibres</th>
<th>Number of fibres</th>
<th>Panel test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
<td>Cooked</td>
<td>Fresh</td>
<td>Cooked</td>
<td>Fresh</td>
</tr>
<tr>
<td>Round</td>
<td>3.90</td>
<td>0.9871</td>
<td>160</td>
<td>75</td>
<td>46.8</td>
</tr>
<tr>
<td>Tenderloin</td>
<td>2.12</td>
<td>0.1012</td>
<td>100</td>
<td>55</td>
<td>45.04</td>
</tr>
</tbody>
</table>

Source: Abdel Baki et al (1957)
Shourbagy et al (1952) investigated the relationship between age and the iodine and saponification values of depot fat in the camel hump. Gunstone and Paton (1953) examined the fat characteristics of a male bactrian camel and found it to be rich in stearic acid.

Nasr et al (1965) found that the moisture and ash contents of the fat depot in the hump and around the kidneys increases with age while the crude fat percentage decreases. They noted that at all ages the fatty tissue around the kidneys contains a higher percentage of crude fat than does the hump.

The mean refractive index value of perinephric camel fat is 1.456 while the melting point mean value is 51°C for the kidney fat and 50°C for hump fat. It is evident that camel fat has a higher melting point than the body fat of cattle and buffaloes (Moursy et al, 1966).

Shourbagy et al (1952) found that the iodine value of hump fat was 35.3 while Moursy et al (1966) reported the figure as 34.77. The former authors reported that the iodine value is affected by age and that the formation of the oleic acid series decreased as age advanced but only to a certain limit. Gunstone and Paton (1953) stated that camel fat is more saturated than the fat of sheep and cattle and this is reflected mainly in the increased content of stearic acid and the decreased amount of oleic acid. Moursy et al (1966) found that the mean saponification value of the perinephric camel fat was 192.1 and that of the hump 193.5. Shourbagy et al (1952) stated that as age increased acids of high molecular weight took the form of glycerides in hump fat. Moreover, the content of water-insoluble volatile fatty acids, referred to as the Polenske number (P.N.), is higher for hump fat (0.70) than for perinephric fat (0.35) (Moursy et al, 1966).

The acidity of fats, expressed either as acid value or as the percentage of free fatty acids, is considered
a measure of the hydrolysis that has occurred in the fat. Determination of acidity in edible animal fat is important and necessary, as any percentage of free fatty acids in excess of 0.5 calculated as oleic will lead to a burning sensation in the throat when fat is eaten and thus renders the material unpalatable. Moursy et al (1966) found that the percentage of free fatty acids for perinephric fat and hump fat is 0.2256 and 0.2820 percent respectively.

Camel meat products

Sadek (1966) found that the conversion of camel meat to sausages eliminated toughness and reduced the required cooking time. Camel meat sausages can form a highly acceptable cooked meal. Camel meat provides an excellent basis for various manufactured and cured forms of meat. It has highly desirable features as a sausage constituent and because of its superior performance, pigmentation and water-binding capacities, kebab makers often incorporate it with other meats. The prepared camel sausage is closely similar in chemical composition to that of beef. It has been found to be free from coliforms and potential food poisoning organisms. It can be recommended as a safe and reliable source of animal protein for human consumption.

The digestion coefficient of camel meat

Nasr et al (1963), in an attempt to evaluate the digestion coefficient of camel meat protein, found the mean value to be 91.96 percent. Various workers, however, have reported that the digestion coefficient of beef ranges from 96 to 99 percent (Ando, 1955). A great deal of work remains to be done in this field: it is important to compare camel proteins with those of cattle of the same age. The digestibility coefficient must be influenced by the sex, age, plane of nutrition, structure of tissues and methods of preparation and preservation. In the light
of the available data on the chemical composition of camel meat and its digestion coefficient it appears that camel meat is a cheap alternative to other animal proteins.

Consumption of camel meat

Dahl and Hjort (1976) reported that camel meat is rarely consumed by the camel herders of Africa; it is only eaten in critical periods of hunger, when entertaining guests, or for ritual and sacrificial purposes. Moreover, Spencer (1973) stated that the consumption of camel meat is considered a luxury among pastoralists; camels are sometimes slaughtered when approaching death, and may be butchered and eaten after natural death.

Though recent efforts have begun to throw light on the meat producing potential of the camel, there is still little information on the selective breeding of the camel for meat quality characteristics. Chatty (1972) pointed out that since the camel was fast becoming obsolete as a beast of burden the camel nomad has tended to respond by breeding for meat production and Leupold (1968) stated that the only secure future for the dromedary was as a meat animal.

Williamson and Payne (1978) indicated Kenya, Ethiopia, Sudan and Somalia as the major area of Africa in which trade in camels for slaughter appears relatively well developed. The area contains almost half the camel population of Africa. A considerable number of camels are reared for slaughter and the area is a net exporter of camel meat.

Bremaud (1969) pointed to a clandestine trade in slaughter animals over the Kenya/Somalia border, involving 600 - 1 000 camels per month. He estimated that 25 to 30 animals were presented daily at Bulahaji market, and referred to a specially constructed camel abattoir at Archer's Post, where a total of 60 000 animals had been slaughtered over several years. At this facility
products such as meat powder, bone meal, meat extract, fat, hides and manure had been produced. Leupold (1968) estimated that 15,000 animals were slaughtered in Somalia every year. In Ethiopia, Knoess (1976) found that a large number of animals were exported for slaughter to Libya and Saudi Arabia yearly and that the average price paid was about the equivalent of US $0.35 per kg live weight. In Sudan, camels account for 5.4 percent of the national meat and milk producing stock (Wilson, 1978). El Amin (1979) reported that as well as meeting the domestic demand which, from 1970 to 1974, varied between 15,477 and 30,385, Sudan exports camels to Libya, Egypt and the Gulf states.

Alim (1976), in a review of the meat industry of Egypt, indicated that the indigenous camel population had declined by 37.7 percent from 175,000 to 109,000 between 1967 and 1974. The decline coincided with an increase in the slaughter rate from 53,000 to 64,000 camels in 1973 and 1974, during which time the contribution of camel meat to domestic meat supplies rose from 14,000 to 17,000 tons. Dada (1978) estimated that 3,410 animals were slaughtered at one abattoir in Kano between September and December; this would indicate that camels are fairly extensively used for meat in northern Kenya.

In India (Bhargava et al, 1965) and Russia (Keikin, 1976) extensive camel breeding farms are maintained where the dromedaries and the bactrian camels are raised. Commercial operations of this kind are almost non-existent in Africa, where most pastoral breeding and selection efforts have tended to emphasize baggage and riding characteristics more than meat production. This kind of selection has often resulted in distinct riding and baggage camel types and breeds, and these are the varieties which are generally marketed. The animals slaughtered for meat are often worn out, incurably injured or barren (Williamson and Payne, 1978).
REFERENCES

Abdel Baki, M.M. 1955 Studies on the tenderisation of camel meat. Thesis, Faculty of Agriculture, Cairo University, Egypt.


<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Title</th>
</tr>
</thead>
</table>
Knoess, K.H. 1976 Assignment report on animal production in the middle Awash Valley. FAO, Rome. (Mimeographed)


SECTION C

CAMEL ALIMENTATION
THE FEEDS AND FEEDING HABITS OF OLD AND NEW WORLD CAMELS

D.M.R. Newman

Summary

Throughout their world range members of the Family Camelidae are found to be superbly adapted to their respective environments and unique in their utilization of the pastures of these environments.

While many aspects of their anatomy, morphology, and physiology are well documented, considerable research remains to be carried out on camelid husbandry. The precise role and potential of these animals as a viable source of meat, milk and wool in arid range lands will remain open to debate until this research is completed.

Introduction

In any field of animal science, the status of a species as a resource animal for the benefit of man may be gauged by the volume and scope of scientific literature available for that species.

The abundance of information available for the management and wellbeing of the cow, the sheep, the pig, and to a lesser extent the water buffalo and the goat, is proof of man's elected dependence on these species as the whole scope of academic and practical animal sciences, from anatomy through reproduction, biochemistry, physiology, surgery, disease, breeding and management to diet, metabolism and the quality and quantity of the product.

The balance, if not the dearth, of information available for the camel family illustrates its lower
standing when compared with its counterparts. There is much available published information on the academic curiosities of the anatomy, morphology, and physiology of Camelidae but relatively little on the practical aspects of the feeding habits, the evolvement of feeding and management schemes, and the quality and quantity of the usable products of this ancient family. This is despite the fact that camels would appear to be uniquely adapted to the habitats and environments in which they now exist and, in many cases, much more so than the cattle and sheep introduced to supplant them as potential productive units in such areas.

McDonald (1968) sees this as a natural result when applied to ruminant nutrition, as man is bound to study in the first instance those animals that he provides with food directly, rather than those which derive their needs from natural pastures.

Mares (1954) has described an unwritten Somali poem which "covers the art and science of camel (dromedary) husbandry from A to Z". It is very obvious that any attempt to collate all information on the feeding habits of Camelidae would presume an access to all such folklore and more than a working knowledge of the French, German, Russian, and Spanish languages. Undoubtedly, therefore, because of the association of all members of the camel family with ancient and deprived peoples and with harsh and even more deprived lands, there is certainly much more information on the feeding habits of camels than appears in accessible form. A considerable amount of information remains still to be documented if the old and new world camels are to become more productive units.

Much of the knowledge cited here has already been collated elsewhere (Newman, in press), however, every attempt has been made to update and expand on this material to include both work previously overlooked and the results of more recent studies.
CAMELS OF THE OLD WORLD

The camels of the old world comprise two species. The dromedary (Camelus dromedarius) which is to be found in the domesticated state in the semi-desert areas of North Africa, south-west Asia, and India, and in the feral state in the central arid areas of Australia and the bactrian (C. bactrianus) which inhabits the remote and harsh areas of eastern Europe, central Asia, northern China, and Mongolia.

The dromedary camel

The dromedary camel has the widest geographic distribution of all the camelids, and is remarkable for its utility in harsh environments, and its ability to thrive on feed that is not highly regarded as sustenance for most other domestic animals (Sharma and Bhargava, 1963; Knoess, 1977; Williamson and Payne, 1965).

Grazing and browsing on natural pastures

Despite the passage of time the treatise of Leese (1927) remains as the basic source of reference for all studies of the dromedary, including those on its feeding habits. Leitch (1940) reproduced much of the original information of Leese on pasture species eaten by dromedaries, and it is again reproduced here, with an updating where possible of botanical names and content (Appendix). The width of dietary preference of the dromedary is further illustrated by more recent studies (Gauthier-Pilters, 1961; Newman, 1975; Newman, in press) which underline the fact that the dromedary is, by preference, a browse feeder from tree, shrub and forb material.

Most studies have shown the dromedary to select browse species as the major part of its diet, and Newman (in press) has found that shrubs and forbs may comprise up to 70 percent of the diet of Australian dromedaries
during winter, increasing to 90 percent during summer. The morphology of the dromedary and the unique dexterity of its mouth parts enable it to browse upper storey plant material selectively but, despite these specialized capabilities, it is equally well equipped to graze lower storey plant communities, and employs a vacuum cleaner-like technique in virtually "sucking-up" feed, especially prostrate succulents.

Within the wide variety of pastures eaten by dromedaries plant species high in moisture, electrolyte and oxalate content feature prominently. Such species as Acacia, Salsola, and Atriplex appear regularly in its diet, when available, no matter where the geographic location. That many such species are thorny in nature and bitter in taste does not deter the dromedary, but may ensure that this preferred diet-base is largely ignored by other animals (Willms, 1978).

Because shrub and tree material may, in the long term, require a longer regeneration period after being browsed than is the case with grasses, and as these species are regarded as being more susceptible to death from overgrazing (Warren and Maizels, 1977), the feeding habits of the dromedary are often looked upon with disfavour. Whyte (1947) regarded the damage done to vegetation by grazing and browsing in critical areas as frequently disastrous, but it is difficult to differentiate as to where he placed total blame; with dromedaries, sheep, or goats - or with all three animals in combination. Herein may lie the problems which need to be overcome before the dromedary, and indeed all the camelids, can become primary production units of economic importance in arid zones.

The studies of Pearse (1971), Huss (1978), Batanouny (1979) and McArthur, Sayad and Nawim (1979) indicate that a lack of animal feeding management, too large a diversity of animal species feeding in one area and, perhaps above all, the need for man to cut tree and shrub material for firewood, are the major contributory causes of increasing
desertification in arid ranges and not necessarily the feeding habits of one particular animal species. It is significant to note too, that often the material which is collected for firewood comes from shrub species that are preferred feed for dromedaries (Le Houêrou, 1974), and it may be desirable to investigate further the use of animal faecal material as an alternative fuel source, rather than deprive animals of their initial food supply in this manner (Winterhalder, Larsen and Thomas, 1974).

Observed feeding habits of the feral dromedary in Australia (Newman, 1975) indicate that the unmanaged dromedary by nature is adept at preserving its own environment. It will seldom spend long periods feeding in one location, except when watering, and may cover distances of from 50 to 70 km per day even in areas where good feed is plentiful. Concentrations of animals will occur for longer than normal periods where stands of a favoured pasture species have occurred for a particular reason, such as fire or flood. Heavy grazing of Trichodesma zeylanicum and Euphorbia tannensis ssp. eremophila has been observed by the author in the Simpson desert region of central Australia following such circumstances.

The dromedary will also continue eating beyond its immediate needs and a 500 kg animal may lay down up to 200 kg of fat in its hump when such opportunities for heavy feeding occur. Such a fat reserve is sufficient to keep a non-working animal alive for 6 months (Macfarlane, 1977) and helps to carry it through any seasonal period of poor pasture growth (Hira, 1947).

The feeding pressure for the dromedary in Australia, however, is somewhat unique, where the total feral population of 15-20 000 animals may have access to up to 130 million ha (McKnight, 1969, 1976) and normal stocking rates would approximate 1 animal per 50 ha. Despite this difference in stocking rates between those for the feral dromedary in Australia and those for domesticated stock in African and Asian habitats, the feeding habits and
diet of the Australian camel may provide usable information for improved production in those areas.

In a paddock-grazing comparison trial carried out by the author at Alice Springs during 1972, it was found that a pair of three year old camels preferred shrub and forb material as their chief dietary components (up to 70 percent) while pairs of various breeds of cattle and a pair of buffaloes preferred grass material (up to 90 percent). All animals grazed together for a 47 day period at an approximate stocking rate of 1 animal/19 ha and all animals exhibited weight gains in excess of 0.5 kg per day (mean daily weight gains: cattle 0.8 kg, camels 1.1 kg, buffaloes 2.3 kg). Given the fact that the stocking rate was comparatively heavy for rain-fed pasture in this area (recommended 1 animal/22 ha) the pasture in the paddock was seen to be heavily but evenly grazed at the conclusion of the period.

In areas of central Australia where concentrations of feral dromedaries may share grazing areas with cattle from time to time, there are few reports or complaints that the feeding habits of dromedaries interfere with the grazing preferences of the cattle (Letts, Bassingthwaigte and de Vos, 1979). This tends to support the evidence of the paddock trial, that dromedaries and cattle may be able to co-exist on natural pasture without a detrimental effect on the pasture, provided always that management is adequate. It is suggested that this may not be the case with either sheep or goats, however, because of the more intensive feeding habits of these animals and because goats especially exhibit very similar feeding preferences to camels (Carrera and Blake, 1968; Du Toit, 1972; Pratt and Knight, 1971).

Wilson (1978) has found that there is an increase in the numbers of dromedaries being slaughtered for meat in Sudan, following a reduced output from other classes of stock which, he states, are now unable to supply the demand for meat in that area. If this trend becomes general in north African countries, then the fact that
dromedaries appear to be able to maintain a continuous growth rate on rain-fed browse pastures, regardless of good or bad seasons (Wilson, 1978), highlights the need for more substantial and concentrated research into the management procedures necessary to realize the full potential of production from the dromedary (Kazem-Khatami, 1970), and to confirm the costs of its products (Hammam, Hidik, Sherif and Yousef, 1962).

Feeding on irrigated and improved pastures

As reports of grazing trials with dromedaries on irrigated and improved pastures are a rarity, the work of Knoess (1976, 1977) in Ethiopia is particularly significant. In these studies, dromedaries grazing pure alfalfa and over-mature Panicum maximum did not exhibit any signs of bloat while grazing for several weeks on the alfalfa, and were able to maintain body weight and produce a sizeable quantity of milk on both pastures.

While no definite conclusions could be drawn from these trials, chiefly because of the limited study period and the low number of animals used, the results indicate that the dromedary may perform at least as well as sheep, cattle or goats under farm conditions. Again, more concentrated study is needed to investigate this premise further.

To overcome an apparent depopulation of desert areas, and to halt the influx of nomads into already overcrowded villages and towns (Knoess, 1977) it may also be beneficial to look to improve the quality and quantity of rain-fed pastures in areas that are suitable for dromedary production.

Le Houérou (1974) reports that, in the arid zones of the Near East and North Africa, the native ranges are being depleted rapidly and the preference of farmers is changing to cash crops, industrial crops and vegetables and grain, as livestock raising becomes a more
difficult and unproductive occupation. He suggests that an answer to this problem may be the growing of drought-resistant fodder shrubs and trees under rain-fed conditions. A selected list of plant species which have so far proved successful introductions into North African arid areas is included in his report. Two of the major types mentioned, *Atriplex* and *Acacia*, are important native fodder types of the Australian arid zone and feature prominently in dromedary diets.

In areas where irrigated pastures are not feasible it may be pertinent to continue further trial introductions of trees and shrubs which are favoured by dromedaries as fodder. Askew and Mitchell (1978) list the major arid zone fodder trees and shrubs of central Australia. Descriptions and nutritive values of a selection that are known to be eaten by dromedaries are shown in Tables 1 and 2. The digestibility and palatability ratings given in Table 2 are those for cattle; it is believed that camel ratings would be higher.

The viability of these species as introductions is not known, but the obvious qualities that they exhibit as potential fodder material for arid zones should not be ignored. If, as Le Houérou (1974) suggests, such introductions may make it possible to establish settled farming in areas where nomadism is otherwise the only solution, the favour of governments would seem to be guaranteed, and the further establishment of the dromedary as a productive animal could only be enhanced.

The establishment of grass introductions in such areas is historically a greater problem, but a comparatively recent introduction to arid areas of Australia, *Cenchrus ciliaris* (Buffel grass), does appear to offer many attributes worthy of consideration (Flemons and Whalley, 1963). Details of its phenology and nutritive value appear in Tables 1 and 2.

*Cenchrus ciliaris* cv. Gayndah, is a hardy perennial which is frost, drought and fire resistant; it is highly
resilient in the face of heavy grazing and is a proven tool in assisting to solve soil erosion and dust problems (Keetch, 1979). It is not a species preferred by dromedaries in Australia but it is eaten. Cattle will normally reserve it as an emergency fodder, but will also graze it heavily under close management or if other more favoured grass species are not available. It is, therefore, suited for a rotational grazing system involving dromedaries and cattle in a shrub-grassland community.

The dromedary is ideally suited for this type of feeding system, because of both its differing feed preferences to those of cattle, and as it causes minimal trampling damage to ground crops and pastures (Kazem-Khatami, 1970).

Hand feeding

Reports on the types of diets hand-fed to dromedaries to supplement or replace natural feeding are many and varied. Generally it can be said that dromedaries are able to utilize a wide range of agricultural feeds, by-products, and wastes (Knoess, 1977) and that they can be fattened very quickly and cheaply on such rations (Kazem-Khatami, 1970).

The dromedary will generally consume 25-40 kg of good fodder per day (Sharma, 1977), with an additional grain supplement for heavy, working animals (Rao, Gupta and Dastur, 1970). Animals used for special purposes, such as riding and racing, also require additional energy supplements which may include oil, ghee, milk, crude sugar, and turmeric (Yasin and Wahid, 1957).

In India the following forage crops are fed green or dry and as hay: "moth" (Vigna aconitifolia), "mung" (Vigna mungo), "guar" (Cyamopsis tetragonoloba), "sainji" (Melilotus parviflora), "taramira" (Eruca sativa), "shaftal" (Trifolium spp.), and "sarson"
Table 1: Descriptions of selected central Australian fodder trees, shrubs and buffel grass

<table>
<thead>
<tr>
<th>Species</th>
<th>Description</th>
<th>Habitat</th>
<th>Ecology</th>
<th>Phenology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acacia kempeana</strong></td>
<td>3 m shrub. Dense crown of foliage.</td>
<td>Calcareous earths to sandy soils but not heavy soils.</td>
<td>Often dominant species. Fire susceptible.</td>
<td>Flowering and fruiting after effective rainfall.</td>
</tr>
<tr>
<td>(Mimosaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mimosaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ayalaya hemiglauc</strong></td>
<td>7 m shrub Winged fruits</td>
<td>Coarse, sandy soils or clay loams. Rocky hillsides, sandy annual grasslands and alluvial plains.</td>
<td>Small stands. Suckers freely. Suckers damaged by frost. Drought hardy, fire tolerant.</td>
<td>Flowers throughout spring. Fruiting late spring to mid-summer.</td>
</tr>
<tr>
<td>(Sapindaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Atriplex nummularia</strong></td>
<td>3 m shrub Semi-succulent leaves.</td>
<td>Floodouts, semi-saline swamps. Alkaline soils mod. to heavy texture.</td>
<td>Dominant communities.</td>
<td>Flowering and fruiting after any effective rainfall.</td>
</tr>
<tr>
<td>(Chenopodiaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1 cont'd: Descriptions of selected central Australian fodder trees, shrubs and buffel grass.

<table>
<thead>
<tr>
<th>Species</th>
<th>Description</th>
<th>Habitat</th>
<th>Ecology</th>
<th>Phenology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carissa lancelota</td>
<td>Dense diffuse shrub 1-2 m high. Fruits soft and black.</td>
<td>Sandy and sandy loam soils.</td>
<td>Local thickets. Drought resistant, fire tolerant.</td>
<td>Flowering and fruiting usually in summer but can follow effective rainfall.</td>
</tr>
<tr>
<td>(Apocynaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Myoporaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eremophila latrobei</td>
<td>1-2 m shrub with variable habit.</td>
<td>All soil types.</td>
<td>Dominant shrub. Growth occurs during autumn and winter. Drought resistant fire tolerant.</td>
<td>Flowering and fruiting after any effective rainfall.</td>
</tr>
<tr>
<td>(Myoporaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capparis mitchelli</td>
<td>4 m compact tree. Fruit hairy and thickshelled.</td>
<td>Favours lime-stone and clay loam soils. But any soil from sand to clay.</td>
<td>Individual plants or scattered trees. New growth slow. Fire tolerant.</td>
<td>Flowering and fruiting in autumn or late spring depending on rainfall.</td>
</tr>
<tr>
<td>(Capparidaceae)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Description</td>
<td>Habitat</td>
<td>Ecology</td>
<td>Phenology</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------</td>
<td>------------------------</td>
<td>------------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>Santalum lanceolatum (Santalaceae)</td>
<td>3 m shrub. Slightly fleshy fruit.</td>
<td>Sandy soils or sandy loams.</td>
<td>Scattered groups. Flowering occurs semi-parasitic on late winter and tree roots. Often spring. Fruits reproduce by suckering. Fire tolerant.</td>
<td></td>
</tr>
<tr>
<td>Ventilago viminalis (Rhamnaceae)</td>
<td>8 m tree which begins as vine. Characteristic inter-twining trunks.</td>
<td>Prefers sandy soils. Also found on sandy loam and low hills.</td>
<td>Small groups of trees. Regenerates by seed and sucker. Drought resistant and fire tolerant.</td>
<td>Flowering occurs late winter and spring. Fruits in early summer.</td>
</tr>
<tr>
<td>Cenchrus ciliaris cv. Gayndah (Gramineae)</td>
<td>Perennial grass 0.5-0.75 m height. Fine leaf with upright habit.</td>
<td>Prefers limestone soils and sandy loams.</td>
<td>Dominant grass. Drought, fire and frost resistant.</td>
<td>Summer growing season, but can respond to any effective rainfall.</td>
</tr>
<tr>
<td>Species</td>
<td>Palatability</td>
<td>Digestibility</td>
<td>Protein</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------</td>
<td>---------------</td>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>Acacia kempeana</td>
<td>good</td>
<td>low</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Acacia victoriae</td>
<td>moderate</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
</tr>
<tr>
<td>Atalaya hemiglauca</td>
<td>high</td>
<td>low</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Atriplex nummularia</td>
<td>moderate</td>
<td>good</td>
<td>good</td>
<td>moderate</td>
</tr>
<tr>
<td>Carissa lanceolata</td>
<td>good</td>
<td>moderate</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Eremophila longifolia</td>
<td>moderate</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
</tr>
<tr>
<td>Eremophila latrobei</td>
<td>moderate</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
</tr>
<tr>
<td>Capparis mitchelli</td>
<td>moderate</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
</tr>
<tr>
<td>Santalum lanceolatum</td>
<td>high</td>
<td>good</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Ventilago viminalis</td>
<td>high</td>
<td>moderate</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Conchrus ciliaris (Buffel grass)</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
<td>moderate</td>
</tr>
</tbody>
</table>

*Nutritive value ratings t

- **Good**: 55–75, 12–18, > 0.5, 3–5, 0.5–1.0
- **Moderate**: 33–55, 6–12, 0.1–0.5, 1–3, 0.2–0.5
- **Low**: 25–35, 1–6, < 0.1, < 1, < 0.2
(Brassica campestris). Also used for supplementary feeding are green "gram" (Cicer arietinum), wheat, barley, and maize, together with turnips and berseem (Trifolium alexandrinum) (Nanda, 1963; Harbans Singh, 1963; Cross, 1918; Mathur, 1960; Sharma, 1977).

Supplementary feeding is necessary in seasons of poor pasture growth, or when it is not possible to give working dromedaries sufficient time for natural feeding. Ideally the dromedary requires 6 hours for natural feeding, and at least that much time again for rumination. It is customary to allow feeding in the early morning and late afternoon, with grain followed by dry fodder being fed in the evening (Matharu Singh, 1960). Animals which have had a heavy working schedule will benefit if rested completely over the rainy season, to allow them to regain condition (Nanda, 1963).

Under closer management for meat production, dromedaries in feed-lots (Kazem-Khatami, 1970) have been shown to fatten quickly on 15-20 kg of a low-priced daily diet comprising straw, beet-pulp silage, molasses and barley (10-15 percent of ration). Kazem-Khatami also reports an experiment conducted in Khorassan Province (east of Iran), where dromedaries grazing on the tops of growing sugar beet exhibited daily gains of approx. 1 kg (females) to 1.5 kg (males), and were ready for slaughter within 60 days.

The availability of agricultural by-products in areas where more intensive camel management is being contemplated may influence this strategy. Such by-products are available in some regions (Devendra and Raghavan, 1978) and their usage for production from camels rather than other animals (El Hag and Mukhtar, 1978) may be worth closer study.

The author has noted an avid liking for citrus fruit among domesticated dromedaries in central Australia and, as the feeding of citrus pulp has been shown to effect some improvement in sheep and cattle produc-
tion (Cottyn and Boucque, 1969; Rodriguez, 1972), studies on the effects of feeding it to camels may be worthwhile, in areas where this by-product is available.

In all diets for dromedaries salt is an important factor (Peck, 1939). Under nomadic management conditions it is reported that particular care is taken to feed salt if saline pastures are not available. It is believed that without adequate salt animals will lose condition, abort, and give less milk, especially when access has been had to lush pastures (Leitch, 1940; Mares, 1954). Stall fed animals may receive up to 30 g salt daily, but foraging animals may need as little as 1 kg/year, and then only at specific times rather than at regular intervals.

Due to the generally adequate mineral content of the browse species preferred by dromedaries, deficiency diseases are not common, but do occur under certain conditions (Leitch, 1940). Generally these diseases are reported to be due to deficiencies of calcium and phosphorus (Gautam and Bansal, 1972; Durand and Kchouk, 1958) and these may be remedied by feeding 100-200 g of bone-meal or similar daily. Studies on such deficiency diseases, as with much other work on the dromedary, have tended to be shallow and inconclusive, and the influence of parasite burdens on camel condition needs to be investigated in much more detail (Bali, et al., 1978).

The bactrian camel

The two humped camel exists in both the wild and domesticated states, and inhabits mainly the areas of central Asia, eastern Russia and Mongolia.

The chief concentrations of the wild "hartagai" camel are believed to be in the deserts of Mongolia and northern China (Tsevegmid and Sashdorj, 1974; Bannikov, 1975), while the main evidence of domestication comes from Turkmeniya (Turkmenistan) and surrounding provinces, and Mongolia.
It is reported from Turkmeniya that 30 million ha of land have been utilized to graze some 4.5 million sheep and 70,000 camels (Nikolayev, 1974), while in Mongolia it is said that 650,000 bactrians are in use for transportation and racing, and for the production of hair, milk, meat and hides (Anon., 1979; Russell, 1977).

The main natural feeding pastures of these areas are comprised of *Artemisia, Artemisia - Salsola*, and *Artemisia - ephemeral associations* (Larin, 1947).

During the summer season the bactrian shows a feeding preference for the sweet annual and ephemeral plants, and only when these dry off or disappear do shrubs and legumes begin to dominate its diet. Species such as *Salicornia fruticosa, Suaeda fruticosa*, and *Limoniastrum monopetalum* are favoured in addition to *Frankenia, Artemisia* and *Salsola* species.

The bactrian is well adapted to the use of such pastures and shows the ability, common to all camelids, to browse selectively the most tender parts of the thorny species, such as *Alhagi camilorum* (Chashkin, 1975).

In the severe winter season natural pastures are covered by snow and only the plant tops may be accessible. These are usually low in nutritive value, and only bactrians with a good hump reserve may survive on this depleted diet without supplemental feeding. Animals may lose up to 20 percent of their body weight if left to exist only on the available natural feed (Chashkin, 1975). Tables 3 and 4 show the seasonal availability and estimated consumption of preferred natural pastures in the main bactrian feeding areas.

On bactrian breeding farms and closer managed production units sheltered areas of 5-8 m² per adult animal are often provided during the winter, and heated quarters are set aside for the young calves. Under these conditions hay, chaff, salt and concentrates are fed as a mainte-
Table 3 (Chashkin, 1975): Availability of preferred plant species in bactrian camel feeding areas (expressed as Percentage of Total Feed Available.

<table>
<thead>
<tr>
<th>Pasture species</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First half</td>
<td>Second half</td>
<td>First half</td>
<td>Second half</td>
</tr>
<tr>
<td>Salsola</td>
<td>25</td>
<td>15</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Artemisia</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Legume</td>
<td>10</td>
<td>60</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Grasses</td>
<td>75</td>
<td>50</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Others (e.g.</td>
<td>40</td>
<td>70</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Haloxyylon sp.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4 (Larin, 1947): The estimated calendar grazing by bactrian camels of principal shrubs in the deserts of South Kazakhstan, Uzbekistan, Turkmeniya and Karakalpaskaya (U.S.S.R.) (expressed as Centners (50 kg) per Hectare).

<table>
<thead>
<tr>
<th>Pasture species</th>
<th>Period</th>
<th>Consumed dry herbage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artemisia herba-alba, or A. maritima ssp. terrae albae - Salsola arbuscula</td>
<td>Autumn to winter</td>
<td>2.5 - 3.5</td>
</tr>
<tr>
<td>Artemisia - Anabasis salsa</td>
<td>Spring</td>
<td>3 - 4</td>
</tr>
<tr>
<td>Salsola gemmascens</td>
<td>Autumn to winter</td>
<td>4.5</td>
</tr>
<tr>
<td>Ephemeral - Salsola associations</td>
<td>Winter</td>
<td>4.5</td>
</tr>
<tr>
<td>Ephemeral - Cruciferae</td>
<td>Winter</td>
<td>4.5</td>
</tr>
<tr>
<td>Artemisia - Salsola gemmascens associations</td>
<td>Winter</td>
<td>3 - 4.5</td>
</tr>
<tr>
<td>Convolvulus - Carex physodes sand associations</td>
<td>All year</td>
<td>3.5</td>
</tr>
<tr>
<td>Convolvulus - Alhagi - Carex associations</td>
<td>Spring to summer</td>
<td>4.6</td>
</tr>
<tr>
<td>Aristida - Arthrophytum associations</td>
<td>Winter</td>
<td>2.3</td>
</tr>
<tr>
<td>Arthrophytum - Carex associations</td>
<td>Winter</td>
<td>3.4</td>
</tr>
<tr>
<td>Alhagi camelorum associations</td>
<td>Spring to winter</td>
<td>5.7</td>
</tr>
<tr>
<td>Glycyrrhiza glabra associations</td>
<td>Autumn</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Table 5 (Ponce del Prado, 1977): Pasture species constituting preferred diet of camelids in Peru.

<table>
<thead>
<tr>
<th>Species</th>
<th>Local plant name</th>
<th>Species family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alchemilla pinnata</td>
<td>sillu sillu</td>
<td>Rosaceae</td>
</tr>
<tr>
<td>Azorella biloba</td>
<td>k'upi k'upi</td>
<td>Umbelliferae</td>
</tr>
<tr>
<td>Agrostis breviculmis</td>
<td>-</td>
<td>Gramineae</td>
</tr>
<tr>
<td>Altensteinia paludosa</td>
<td>-</td>
<td>Orchidaceae</td>
</tr>
<tr>
<td>Arenaria lanuginosa</td>
<td>han alli</td>
<td>Caryophyllaceae</td>
</tr>
<tr>
<td>Aster acaulis</td>
<td>-</td>
<td>Compositae</td>
</tr>
<tr>
<td>Azorella yareta</td>
<td>yareta</td>
<td>Umbelliferae</td>
</tr>
<tr>
<td>Bromus unioloides</td>
<td>-</td>
<td>Gramineae</td>
</tr>
<tr>
<td>Bougueria rubicola</td>
<td>-</td>
<td>Plantaginaceae</td>
</tr>
<tr>
<td>Bartschia gracilis</td>
<td>misa ti'ica</td>
<td>Scrophulariaceae</td>
</tr>
<tr>
<td>Calamagrostis vicunarum</td>
<td>wikuna pastu</td>
<td>Gramineae</td>
</tr>
<tr>
<td>Calandrinia acaulis</td>
<td>gapaso</td>
<td>Portulacaceae</td>
</tr>
<tr>
<td>Distichia muscoides</td>
<td>kunkuma tajlla</td>
<td>Juncaceae</td>
</tr>
<tr>
<td>Plantago manticola</td>
<td>ichu ichu</td>
<td>Plantaginaceae</td>
</tr>
<tr>
<td>Senecio rhizomatus</td>
<td>tikllai warmi</td>
<td>Compositae</td>
</tr>
</tbody>
</table>

Amelioration diet. Hay-making from natural pastures is a common practice to provide reserve winter fodder.

Great attention is paid to the needs of the young camels on these breeding farms. All milk from females with young calves is reserved for the calves and artificial milk may be fed to slower developing animals. In addition to this, from 200 - 1 500 g of concentrates may be fed daily to assist them through the period from 6 - 7 months of age, when natural milk is usually exhausted, to 12 - 18 months of age, when the calves move on to a complete pasture diet (Chashkin, 1975).
In all feeding situations it has been found that an adult bactrian (500 kg) may require from 24 - 27 kg of green pasture material per day for production, or 6 - 12 kg of good quality hay or chaff, and concentrate. A minimum of 100 g salt per animal per day is dispensed with a dry diet (Chashkin, 1975).

CAMELS OF THE NEW WORLD

The new world camelids, sometimes erroneously referred to as the auxenidae, are to be found in the inhospitable and cold regions of the high Andes of South America. This branch of the Camelidae family is comprised of the llama (Lama glama), the guanaco (Lama guanicoe), the alpaca (Lama pacos), and the vicuña (Lama vicugna).

The llama

The only pre-Columbian new world beast of burden, the llama (Plate 3, p 137) is said to be the work horse of the Andean Indian (Hugh-Jones and Bacon, 1964). It has similar resilience to the camels of the old world in that it can exist on little food while travelling long distances, and may remain without substantial food for 5 days with no significant effects (Link, 1949).

The preferred habitat of the llama is the dry tableland areas of Peru and Bolivia (3000-5000 m) where the dominant natural vegetation is associations of Stipa spp., and Festuca spp. (French, 1966; Link, 1949). It is reported by French that the llama is a very rustic and frugal animal which can live on moss and lichen-covered slopes, and that it is able to utilize pastures which cannot support its near relatives, the alpaca and vicuña. Its habit of feeding on the coarse Stipa grasses and scrub bushes is evidenced by observations that the teeth of some populations are kept continually short by
the action of feeding on these coarse pastures (Hugh-Jones and Bacon, 1964).

The frugality and resilience of the animal are demonstrated by the fact that it may be content with the few mouthfuls of hardly noticeable grass that it is able to obtain in the mornings and evenings, or in the short occasional rest periods in a long days haul of 15-20 km carrying loads of up to 80 kg (Link, 1949; French, 1966).

The guanaco

The guanaco is the tallest South American feral animal and mainly inhabits the Patagonian plains of Argentina (Boswell, 1973). It is the wild relative of the llama and is very nervous when approached (Pearson, 1951; Prichard, 1902) (Plate 1, p 137).

Little information is accessible on the feeding habits of this animal (Newman, in press) but it is reported to favour barren and dry conditions, and its dietary preferences are probably similar to those of the llama (Link, 1949).

It is interesting to note that the sheep farmers of Patagonia at one time urged the total extermination of the guanaco, alleging that it ate many times as much pasture as did sheep. Dennler (1954) stated that this prejudice overlooked the fact that the guanaco feeds chiefly on grasses and leaves and buds of bushes which are inaccessible to sheep.

The alpaca

The alpaca(Plate 4, p 137) is regarded commercially as the most important of the South American camelids (Newman, in press). It is favoured for its wool and meat production and on good pasture may produce up to
500 ml of milk daily (Russell, 1977; Bonadonna, 1969; Novoa, 1970). French (1966) states that 4-5 million Andean Indians derive their livelihood from it, either directly or indirectly.

Its habitat is the high tablelands of Peru and Bolivia (Link, 1949) and it is best managed in herds of 150 - 300 at elevations above 4 000 m, or as high as there is feed (French, 1966; Pearson, 1951). Fernancez-Baca (1975) has found that the alpaca surpasses sheep in its ability to utilize these high altitude grasslands where it can be grazed at a capacity of 1.5 to 3 animals per ha.

The preferred diet of the alpaca comprises the soft succulent grasses occurring in the moist and marshy soils of the valleys of the Cordillera regions. The water grass "tortora" (Scirpus spp.) and the water weed "llacho" (Myriophyllum titicacensis) are sought-after species and yield excellent fodder of high protein content (Guilbride and Moros, 1965). Low quality woody and fibrous species of Festuca, Muehlenbergia, Aciaehne and Calamagrostis also feature in the diet of the alpaca (Vallenlas, 1965).

The vicuña

The handsomest of the Western Hemisphere camels (Plate 2, p 137) this delicate and deer-like animal with the "golden fleece", inhabits the bleak, blizzard-swept, treeless altitudes of the Andes (puna), from Peru to the north of Argentina (Hodge, 1950; Link, 1949). Koford (1957) concluded that the limits of the vicuña's range are usually from 3 700 - 5 000 m and are determined not by altitude, but by availability of feed and by freedom from disturbance.

The vicuña is said to rank as the inferior species in any interspecific competition for space and food (Jungius, 1971), and this can result in its total dis-
placement from favourite feeding areas when confronted by large herds of other animals, such as alpacas.

Aside from resting, Koford (1957) found foraging for feed to be the principal daylight activity of the feral vicuña in all seasons. The need for food was adjudged to be greatest in summer when the additional stresses of reproduction and mating imposed a higher level of nutritional requirement. This additional requirement coincides with the longer daylight hours of the season and with the increased availability and succulence of the pastures, indicating the adaptability of the vicuña to its habitat.

Observations of the feeding habits of bands of vicuñas (Koford, 1957) showed that early morning feeding was unhurried and selective and interrupted by rest periods and intergroup encounters. This contrasted with the vigorous feeding late in the day to enable a good stomach fill for a night of rest and rumination.

This diurnal feeding pattern can again place the vicuña in conflict with the alpaca for feeding areas, as the alpaca has similar habits. The vicuña is, therefore, often forced to leave favoured pastures, and retire to bordering areas where the moist vegetation peters out and is replaced by pastures of poorer nutritive value. The ability of the vicuña to make use of these biotypes with poorer vegetation is very significant, and in the future this attribute should be exploited as a management tool in developing the potential productivity of the vicuña (Jungius, 1971).

The principal food of the vicuña appears to be the succulent grasses Festuca rigescens and Calamagrostis nitidula which border streams; and the mosses, lichens and short rushes in poorly drained hollows (Link, 1949; Pearson, 1951; Hodge, 1950; Koford, 1957). On the puna plateaus the grasses Calamagrostis brevifolia and C. vicunarium are favoured, and in the moister areas of the puna grasslands the succulent forbs, Distichia muscoides
and Werneria sp.; the roots of the small legume Astragalus peruvianus and Senecio sp.; and the small rosettes of the species Nototriche, are sought after by the vicuña (Koford, 1957; Pearson, 1951; Jungius, 1971).

Koford ranks the South American camels in order of a decreasing requirement for succulent feed (alpaca, vicuña, llama, guanaco) and suggests that, as this is also the order of the increasing geographic range of these animals, the seasonal availability of green food and the different ranges of tolerance for dry feed are important factors determining the limits of their distribution. A collective list of pasture species found in the diets of auchenidae in Peru (Ponce del Prado, 1977) appears in Table 5, and Roseveare (1948) gives extensive listings of pasture grasses and shrubs in auchenidae habitats, but, as is the case for all of the camelids, detailed studies of production potential from natural or managed feeding are difficult to find, although some studies have dealt with digestive capabilities either in isolation or in comparative research. (Riera and Cardozo, 1970; Schneider et al., 1974; Von Engelhardt et al., 1975; Hintz et al., 1973; Vallenas and Stevens, 1971).

CONCLUSION

This review has attempted to draw together information that is available on the feeding habits of Camelidae relative to any future role they may have as productive ruminants.

These animals are highly adapted to their peculiar, generally rigorous environments, and appear to constitute an efficient component of an ecosystem in which the flora of usually marginal, sometimes arid or semi-arid, land can be converted to human food and usable products (Reid, 1970).

It is apparent that much has been done to take
advantage of the resource that the bactrian camel provides in the inhospitable regions of eastern U.S.S.R. and Mongolia (Chaskin, 1975). The information relative to this continuing development needs to be sought out and, together with the recommendations of Knoess (1977), applied to the dromedary of northern Africa and India, if an improvement to the semi-nomadic management at present practised in those regions is to be realistically stimulated.

The possibilities for closer management and the greater productivity of the new world camels would appear to depend on many factors. Most significant among these would seem to be the success or otherwise of domestication and breeding programmes for the guanaco and the vicuña (Jungius, 1971); the possibility of increasing the productivity of the Andean rangelands by the introduction of improved forage and fodder species (Fernandez-Baca, 1975), and finally an improvement of the management of natural grasslands inhabited by the llama and the alpaca.

Cuthbertson (1970) concluded that resources to these ends are limited and depend to a considerable extent on industrialization, education and social factors as well as on good animal husbandry. These conclusions may still be valid. It is obvious, however, that animal scientists must fill the gaps in the present knowledge of the potential for productivity from camels if their role as major producing animals is to be realized.
## APPENDIX

Species known to be eaten by dromedaries

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Gyrostemonaceae
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Juncaceae
- Juncus maritimus | Syria | Whyte (1947) |

Labiatae
- Marrubium deserti | Northern Algeria | Gauthier-Pilters (1961) |

Limoniaceae

Loranthaceae
- Amyema maidenii | Australia | Newman (in press) |
- Loranthis acaciae | Sudan | Leitch (1940) |
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REFERENCES


Anon. 1979 in "The Advertiser", Adelaide, South Australia, 122 (37694), September 1st.


Bannikov, A.G. 1975 Wild camels in Mongolia, Oryx, 13, 12.


Boswall, J. 1973 Park in the Andes, Oryx, 12, 243-251.


Cross, H.E. 1918 Some camel-feeding experiments, Imperial Dept. of Agriculture, India, Bulletin No. 77.


de Vos, A. 1976 Personal communication.


El Hag, G.A., and Mukhtar, A.M.S., 1978. Varying levels of concentrates in the rations of


Hira, L.M. 1947 Camel breeding in India, Indian farming, 8, 504-507.


Link, P. 1949 Alpaca, llama, vicuna, guanaco. Ferrari Hermanos, Buenos Aires.


Rodriguez, V. 1972 Effect of different levels of dehydrated citrus pulp as a supplement for cows in free or restricted grazing. Rev. cubana Cienc.Agric., 6, 9-13.

Roseveare, G.M. 1948 The grasslands of Latin America. Imperial Bureau of Pastures and Field Crops, Aberystwyth, Bull. No. 36

Russell, K.P. 1977 The specialty animal fibres. Textiles, 6, 8-12.


Sharma, D.P. 1977 Personal communication.


THE NUTRITION OF CAMELS AND SHEEP UNDER STRESS

M.F.A. Farid, S.M. Shawket and M.H.A. Abdel-Rahman

Summary

Experiments have been carried out at the Desert Institute, Egypt, to provide information on the merits of camels, as compared to sheep as a productive unit in arid zones. Animals were fed low protein roughage diets containing an estimated level of digestible crude protein of approximately 4 percent. They were watered daily, or intermittently every three days for sheep and every twelve days for camels.

Results indicate that camels needed less water per unit DM intake or per unit body mass (Kg \(0.82\)). Sheep lost more water in urine than camels. In general, camels were superior in conserving water during water-deprivation periods and in reducing its losses in faeces to about half the control value.

Camels digested dry matter and crude fibres slightly more, and crude protein slightly less, than sheep. Water deprivation improved apparent digestibilities more in sheep than in camels.

Camels were in a better state of nitrogen balance throughout the experiments. Nitrogen retention was improved during water deprivation, more so in camels than in sheep. This was achieved through reduction of nitrogen excretion in both faeces and urine in the camel, whereas sheep reduced only their urinary losses.

Under present experimental conditions, it appears that nitrogen conservation was not achieved through increasing recycling of urea to the rumen. Camels usually recycled more urea than sheep, 0.20 g against 0.14 g N/Kg\(0.75\)/day. Water deprivation reduced these values to one-third in sheep and one-half in camels.
Another important difference between camels and sheep was noticed in their rumen protozoal population. *Entodinium* sp. formed 70 percent of the population in both species. *Holotricha* sp. made up to 10 percent of the population in sheep but was absent in camels. Conversely, *Epidinium* was found in the rumen of camels but not in sheep. In general, water deprivation decreased *Entodinium* sp. and total protozoal count in sheep, but it increased in camels with the total count remaining practically constant.

Introduction

Characteristic problems in the management of ruminant animals in arid and semi-arid zones appear to be the seasonal shortage of feed and of free drinking water (Payne, 1966). The problem is generally viewed only in terms of proper stocking rates. Many specialists advocate that stocking rate must be kept within the carrying capacity of grazing during the dry season. This would require a reduction in the present level of animal production. The human population is increasing, as is the demand for meat and other animal products.

An alternative approach to the problem of carrying capacity lies in making available supplementary feeds and water and the use of a low level nomadic form of grazing (Payne, 1963) during the dry season when combined feed and water deprivation is liable to occur. Experimental data suggest that moderate water deprivation is likely to be advantageous to the animal if there is inadequate forage available during the dry season (Livingston et al, 1962; Payne, 1963 and 1966; Rogerson, 1963).

It is also feasible and probably more economic to utilize semi-arid grazings by farming game and the less popular domesticated ruminants such as the camel in addition to sheep and cattle. In this regard it has been the general opinion in Egypt and elsewhere that
excluding the camel from arid and semi-arid grazing lands furthers desertification by encouraging the invasion of such rangelands by plant species unpalatable to sheep.

Results are summarized of experiments conducted at the Desert Institute, Egypt, on the comparative effect of water deprivation on water and nitrogen economy in camels and sheep when fed a low protein, all-roughage diet under simulated drought conditions. Urea recycling to the rumen, and the rumen protozoal population were also investigated (Shawket, 1976; Abd-el-Rahman, 1978).

Materials and methods

Two local Barki rams and two female dromedaries were used in each of two experiments. Animals were housed individually in a closed barn for the duration of the experiment, sheep in metabolism cages and camels on the floor.

Feeding and management

All animals were fed a low protein roughage diet consisting of 70 percent wheat straw and 30 percent berseem (Trifolium alexandrinum) hay, chopped and mixed together. The mixture contained approximately 1.2 percent nitrogen on a dry matter basis.

The diet was offered in amounts to satisfy maintenance energy requirements and only 50 percent of the digestible crude protein requirement according to British Standards (Agricultural Research Council, 1965). Since the nutritional requirements of the camel are not known, those for cattle of comparable body weights were used.

Rations were offered once daily at 09.00 hours and
any rejected feed was collected, weighed and sampled the following morning. Drinking water was offered ad libitum once daily in the morning or as specified for the different experimental treatments.

During the course of the experiments animals were weighed at intervals before the morning feed.

Experimental treatments

Animals were subjected to two water treatments during successive experimental periods. The first was a control period of 50 days when they were watered once daily. The last nine days of the period were assigned for total urine and faeces collection in a conventional digestion and nitrogen balance trial.

During the second period, camels and sheep were subjected to water deprivation. Sheep were watered once every 3 days and camels every 12 days. At the end of the period conventional digestion and nitrogen balance trials were conducted. These lasted 9 days for sheep and 12 days for camels.

At the end of each period, periodic rumen and jugular blood samples were withdrawn for the determination of rumen ammonia and blood urea nitrogen concentrations, before feeding and at intervals after feeding.

Digestion and nitrogen balance trials

Trials were conducted in the conventional manner employing total faeces and urine collection. Faeces were collected in rubber-lined collection bags attached to a harness fitted to the animal. Urine was collected using metal funnels fitted around the external genitalia of the female camel or around the prepuce of the sheep and draining into bottles containing sulphuric acid.
Faeces and urine were collected daily from each animal in the morning and 5 percent samples of each were saved. Faecal samples were dried and bulked over the entire collection period. Urine samples were also composited.

Rumen fluid volume determination

Rumen fluid volume was determined before feeding and at 2 and 6 hours after feeding during the control periods and at 6 hours after feeding during the water deprivation period. The chromium - EDTA method of Binnerts (1968), modified by El-Shazly (unpublished) was used.

At the specified time a dose was introduced into the rumen via the cannula and samples taken every two hours for the following ten hours. Chromium concentrations were determined colorimetrically and rumen fluid volume calculated by regression analysis.

Measurement of urea recycling to the rumen

A technique similar to that used by Weston and Hogan (1967) for sheep and Vercoe (1969) for cattle was adopted. Infusions were carried out by gravity drip assembly.

Urea was infused intraruminally and intravenously at different rates and the effect on ruminal ammonia concentration was evaluated. Infusions were carried out for 10 hours, starting at 12 hours after feeding. Rumen samples for the determination of ammonia were withdrawn every two hours between 12 and 24 hours after feeding. An average value from the 18, 20 and 22 hour samples were used. Figures 1, 2 and 3 illustrate the procedure.

During the control period, and during water deprivation (days 1, 2 and 3 in sheep, and days 3, 6, 9 and
12 in camels) the same procedure was carried out. Rates of infusion (Figure 3) were similar in both species on the basis of unit metabolic body size. The rate of IV infusion was chosen to insure maximum urea transfer to the rumen (Figure 2). Appropriate regression equations were calculated and net urea transfer was estimated.

Rumen protozoa counts

Samples of rumen contents were withdrawn before feeding and at 2 and 6 hours after feeding. Total and differential counts were carried out according to the method of Naga and El-Shazly (1969).

Analytical procedures

The constituents of feedstuffs, feed refusals and faeces were determined by official procedures (Association of Official Agricultural Chemists, 1960). Total nitrogen in urine was determined by the micro-Kjeldahl method, and the Markham micro-distillation apparatus and determined by titration (Markham, 1942).

Rumen ammonia and blood urea nitrogen were determined by the method of Van Slyke (Hawk et al, 1953). Rumen total volatile fatty acids were distilled in a Markham (1942) micro-distillation apparatus and determined by titration.

Results

Bodyweight changes

Absolute and relative daily weight changes of sheep and camels are presented in Table 1. Both sheep and camels lost weight during the control period as a result of feeding the low-protein roughage diet. Sheep were more severely affected by protein deficiency. Relative weight losses were 3.15 g/day/kg for sheep as compared to 0.58 g/day/kg for camels.
When sheep and camels were further exposed to water deprivation, weight losses increased. On a relative basis sheep still lost more weight than camels; 4.88 g/day/kg for sheep vs. 3.18 g/day/kg for camels.

Water intake and excretion

Since parameters of water metabolism are better related to body mass, $kg^{0.82}$, for inter-species comparisons (Macfarlane and Howard, 1970), results are expressed accordingly (Table 2). Results indicate that, in general, sheep need more water and lose more water than camels.

During the control period sheep needed more water per unit body mass and per unit dry matter intake than camels. They also lost more water as a percentage of free water intake. Main avenues for water excretion differed in the two species. Sheep excreted more water in urine whereas camels excreted more in faeces.

Under the effect of water deprivation, sheep drank about the same as in the control period per unit body mass, but less per unit dry matter intake. Water deprivation did not seem to affect the magnitude of water excretion in sheep, either in faeces or in urine, whether as percentage of intake or per unit body mass. However, faecal water output per unit of faecal dry matter decreased.

Camels, on the other hand, showed a decrease in free water intake during water deprivation, both per unit body mass and per unit dry matter intake. Water excretion in faeces decreased, whereas urinary water excretion was not apparently affected when expressed on a relative basis.

In general, it seems that camels are more efficient than sheep in conserving water when exposed to water deprivation. It also appears that the regulation of faecal water excretion is the more important means of water conservation.
Feed intake and digestion

During the control period both sheep and camels refused portions of their offered ration and consumed similar amounts of the low protein all-roughage diet (Table 3). Probably as a result of adaptation, sheep distinctly increased their feed intake during the water deprivation period. Camels, however, showed only slight changes in feed intake throughout the experiment.

The water deprivation treatment improved the apparent digestibility in sheep of all nutrients other than crude fibres. In camels, the digestibility of dry matter, crude protein and the nitrogen-free extract improved; that of ether extract decreased and crude fibre digestibility was practically unaffected.

Water deprivation improved the intake of total digestible nutrients (TDN) in sheep as a result of increased dry matter intake and improved digestibility. In camels TDN intake decreased slightly during water deprivation, reflecting the small changes in both dry matter intake and the apparent digestibility of nutrients.

Nitrogen balance

It was observed that sheep consumed twice as much nitrogen as camels per kg$^{0.75}$ throughout the experiment (Table 4). Differences in selectivity, sheep being more selective than camels, were probably the main factor contributing to these differences in nitrogen intake between the two species. During the control period both camels and sheep consumed nearly the same amount of dry matter per kg$^{0.75}$, but sheep still consumed twice as much nitrogen, 0.411 vs 0.220 g/N/day/kg$^{0.75}$.

Water deprivation increased nitrogen intake by an average of 29 percent in sheep and 23 percent in camels.

Faecal nitrogen excretion was greater in sheep
during water deprivation, reflecting higher intake and a nearly constant digestibility. During the control period, on the other hand, faecal nitrogen excretion was only slightly above that of the camel irrespective of its greater intake. This was due to poor nitrogen digestibility by camels during the control period.

In effect, digestible nitrogen intake improved by 34 percent in sheep during water deprivation mainly because of increased intake and the slightly improved digestibility (Tables 3 and 4). In camels, digestible nitrogen intake improved 150 percent during water deprivation due mainly to the distinct improvement in digestibility.

The excretion of nitrogen in the urine (Table 4) followed a pattern similar to that of faecal nitrogen excretion as far as the comparison between species is concerned. Sheep excreted more nitrogen than camels. Water deprivation appears to have had a minor effect. In sheep it caused a slight decrease in urinary nitrogen, and a slight increase in camels.

Nitrogen balance, the end result of the above described transactions, was generally to the advantage of the camel. Sheep lost more nitrogen per unit metabolic size, kg W^{0.75}, during both control and water deprivation treatments. Furthermore, water deprivation improved the nitrogen balance fivefold in camels and only threefold in sheep. It therefore appears that as far as the overall nitrogen economy of the animal is concerned, camels surpass sheep on low nitrogen intakes, and can withstand better and benefit more from water deprivation.

The advantage of the camel is also evident from inspection of relative nitrogen excretion in faeces and in urine by both sheep and camels (Table 4). In terms of percentage of nitrogen intake, camels reduced their faecal nitrogen output during water deprivation whereas sheep did not. As percentage of digested nitrogen, both sheep and camels reduced urinary nitrogen.
output, but this was more marked in the camel. It is therefore considered that the camel achieved nitrogen conservation during water deprivation through both the faecal and urinary pathways, whereas for sheep the urinary pathway was more important.

Rumen fluid volume

The size of the rumen fluid volume compartment in camels and sheep, and the changes induced by water deprivation are summarized in Table 5. There were no species differences when volume was expressed per unit of body mass (m 1/kg$^{0.82}$). On the other hand, sheep had a larger volume per unit of live body weight (m 1/kg).

Water deprivation seemed to affect the rumen volume of camels and sheep similarly. It increased on watering days, then decreased gradually as water deprivation progressed. On watering days, the camel expanded its rumen volume more than sheep. The control values were similar, 301 and 305 m 1/kg$^{0.82}$ in the camel and sheep respectively. On watering days, these values were 449 ml/kg$^{0.82}$ in the camel and 352 in sheep.

Furthermore, sheep lost more rumen water during water deprivation than camels (Figure 4). This, along with the capacity to expand the rumen volume on watering days may represent an adaptive phenomenon in the camel, being of importance under conditions of severe drought.

Rumen and blood metabolites

Total fatty acid concentrations were generally slightly lower in camels than in sheep (Table 6). In both species there was a slight or nil decrease in concentration at 2 hours after feeding, followed by an increase at 6 hours after feeding.

Total acids in the rumen at 6 hours after feeding
tended to decrease as water deprivation progressed (Table 7), probably a result of decreased feed intake.

The ration equivalent VFA at 6 hours after feeding per g TDN intake was lower in camels than in sheep during the control period. During water deprivation, on the other hand, the ratio decreased in the sheep, whereas it increased in the camel.

During the control period, rumen ammonia nitrogen concentration in sheep increased at 2 hours after feeding, then it decreased at 6 hours (Table 8). There was no peak at 2 hours after feeding in the camel. During water deprivation, concentrations were greater in sheep than in the camel. Again, the 2 hour peak was not recognized in the camel.

Lower concentrations and the absence of the 2 hour peak in the camel are expected to slow absorption. Thus less ammonia nitrogen would be wasted. The longer retention of ammonia in the rumen makes it more available for microbial protein biosynthesis, and for better utilization of nitrogen.

Results of blood urea nitrogen measurements are presented in Table 9. During the control period in sheep, blood urea nitrogen reached a peak at 4 hours after feeding. In the camel, on the other hand, it was generally lower than in sheep, and it increased slowly after feeding reaching a maximum at 8 hours.

During water deprivation, concentrations were much higher than the control values in sheep, and showed the characteristic peak at 4 hours. In the water deprived camel, the pattern was closely similar to that observed during the control period. Concentrations were again lower than in sheep.

Here again, as in the case of rumen ammonia, the lower concentration in camels indicates a better nitrogen economy than that of sheep.
Urea recycling in the rumen

Results of estimated net urea transfer to the rumen in camels and sheep are summarized in Table 10. The amount of urea recycled from infused urea could not be determined since the amount recycled from the basal diet was not estimated. Therefore, the term "net transfer" was adopted.

Under these experimental conditions, camels transferred more urea to the rumen than sheep, expressed per unit metabolic body size (kg \(0.75\)).

These values were 201 and 140 mg N/kg\(0.75\)/day for camels and sheep, respectively, during the control period.

Urea transfer decreased progressively as water deprivation progressed, even though blood urea nitrogen concentrations increased. It increased in the camel up to the third day of water deprivation before it decreased again. After 12 days of water deprivation, camels recycled urea at a rate similar to that of sheep deprived of free water intake for only two days.

Total and differential rumen protozoal count

The total rumen protozoal count, determined 6 hours after feeding, along with the species percentages are summarized in Table 11.

The total count, per ml of rumen fluid, was in general greater in sheep than in camels during both control and water deprivation periods. The total count per ml or per rumen, decreased in both species during water deprivation. The camel was apparently less affected than sheep. The total count per rumen increased over the control value on watering days, and after 4 days it was similar to the control.
Striking differences were observed in the protozoal species between camels and sheep. In both, _Entodenium_ sp. contributed at least 62 percent of the total population. However, _Epidenium_, _Metadenium_ and _Eudiplodenium_ were identified in the camel but were absent from the sheep rumen. Conversely, 5 other species were found in the rumen of sheep but not in the rumen of the camel. These were _Diplodenium_, _Ophreascolex_, _Astrochadenium_, _Palyplastron_ and _Holotricha_ sp.

In the camel, water deprivation increased _Entodenium_ but decreased the other three species. In the water-deprived sheep, on the other hand, _Entodenium_ decreased whereas the other five species increased. Since _Entodenium_ sp. comprised more than two-thirds of the population, changes in this species were directly reflected upon the total population count in both camels and sheep.

Discussion

The results of these experiments indicate that the camel is better adapted to arid zone conditions than sheep. Both camels and sheep lost weight throughout the experiment due to dietary protein deficiency, but the relative weight loss was greater in sheep. Also, sheep benefitted less from water deprivation. Camels survived the experiments whereas both sheep died. Similar results were reported by Macfarlane _et al._ (1956), Macfarlane _et al._ (1963) and Payne (1966). The smaller losses in camel live body weight during water deprivation could be attributed at least in part to smaller losses of water in sweat, respiration, urine and faeces (Schmidt-Nielsen _et al._, 1956) and to the lower metabolic rate of the camel (Macfarlane _et al._, 1963).

During the control daily watering period, sheep needed more water than camels whether expressed per unit of body mass, kg W^0.82_, or per unit of dry matter intake. Similar results were reported for these two species (Macfarlane _et al._, 1963) where sheep had a faster turnover rate of total body water. Water depri-
vation reduced free water intake as reported earlier. (French, 1956a, b; Payne, 1963, 1966). Sheep needed more water than camels whether as a function of dry matter intake or of body mass.

The differences between sheep and camels in their need for free drinking water, and in their response to water deprivation, may be attributed to adaptability. *Bos taurus* was more severely affected by nutritional stress and water deprivation than *Bos indicus* (Livingstone et al., 1962; Payne, 1963). Payne (1966) and Weeth and Lesperance (1965) reported that adapted cattle seem to reduce their free water intake less than non-adapted ones when subjected to water deprivation for up to 72 hours. Differences in the turnover rate of total body water (Macfarlane et al., 1963) and the camel's lower metabolic rate were noted.

Camels consistently lost less total water in faeces and urine, expressed as percentage of free water intake, during both control and water deprivation periods. During water deprivation the superiority of the camel was clearly evident. Water conservation was attained through reduction of both faecal and urinary water, the reduction of faecal water being the more significant. Sheep seemed to conserve water less efficiently but, again, regulation of faecal water excretion was the more important pathway for water conservation. This regulatory role of the lower bowel upon faecal water excretion is believed to provide water to balance losses from the extracellular fluid compartment during dehydration (Thornton and Yates, 1968). Rumen water is utilized during dehydration in a similar way (Hecker et al., 1964).

Macfarlane et al. (1963) reported on the lower needs of camels for free drinking water, and on their lower excretion rates as compared to sheep. This ability to conserve water enabled the camel to withstand prolonged dehydration (Schmidt-Nielsen et al. (1956). In addition, camels have an economic sweating system for evaporative
cooling which wastes less energy and water than the more expensive respiratory cooling of the sheep.

Dry matter intake and free water intake are closely related (Clark and Quin, 1949; Phillips, 1960). It is believed that this maintains a physiological balance between rumen water and rumen dry matter content, i.e. to maintain a stable specific gravity in the rumen compartment (English, 1966). During water deprivation the reduction of free water intake did not result in a corresponding reduction in dry matter intake either in sheep or in camels. It seems that long adaptation to water deprivation had enabled the animals to maintain the level of dry matter intake per unit metabolic size, kg W^{0.75}. As a matter of fact, sheep consumed more dry matter during water deprivation than during the control period. This differs from earlier reports on cattle (Larsen et al., 1917; French, 1956 a, b), and on sheep (Clark and Quin, 1949; Gordon, 1965).

When camels and sheep were watered daily, camels digested dietary constituents other than nitrogen better than sheep. Water deprivation in sheep improved the digestibility of all nutrients except crude fibre. This is in general agreement with reports by other investigators. (Larsen et al., 1917; French, 1938; Balch et al. 1953; French, 1956 a,b; Phillips, 1960), although most investigators reported improved crude fibre digestibility as well.

On the other hand, digestibility of nutrients in the camel did not show a consistent response to water deprivation. Only the apparent digestibility of nitrogen showed a distinct improvement during water deprivation.

It is noteworthy that camels were peculiar in their feeding habits. They were slow eaters and continued to eat over the 24 hours of the day and night. They were not as selective as sheep. The straw and chopped hay were offered mixed together. Sheep were able to select
and eat the hay first and refusals, if any, were mostly of straw. The camels were unable to select the hay which was eaten together with the straw.

Differences in selectivity may appear to have been to the disadvantage of the camel. However, our present observations are of limited value in relation to natural grazing conditions, where it is expected that the types of diets selected by grazing camels and sheep would be completely different.

Under the present experimental conditions, observed differences in selectivity explain differences in nitrogen intake between camels and sheep even though dry matter intakes were similar, where sheep consistently consumed twice as much as nitrogen as camels.

It is not clear at this point whether the lower rumen ammonia and blood urea nitrogen concentrations observed in the camel were a characteristic of this species, or if they were a reflection of differences in selectivity and consequent lower nitrogen intake.

In spite of their lower nitrogen intake, camels utilized nitrogen better than sheep. Sheep excreted more urinary nitrogen per unit of metabolic size. Throughout the experiment camels were in a better state of nitrogen balance than sheep.

Water deprivation improved nitrogen retention in both camels and sheep. Camels approached equilibrium and nitrogen conservation was achieved through reduction of the portion of digested nitrogen lost in urine. In addition, camels reduced faecal nitrogen output whereas sheep did not.

Schmidt-Nielsen et al. (1957) reported that when a grazing camel was maintained on a low nitrogen intake, the amount of nitrogen excreted in urine decreased from 13 g/day to 2-3 g/day, and urea nitrogen fell to very low levels. Several authors (e.g. Schmidt-Nielsen
et al., 1957; Schmidt-Nielsen and Osaki, 1958; Livingston et al., 1962; Payne, 1963, 1966) showed that nitrogen conservation in the water-deprived ruminant is attained through reduction in the excretion of urinary urea nitrogen. These findings are in agreement with our present results, camels being more efficient in nitrogen conservation than sheep.

Schmidt-Nielsen et al. (1958) described the role of the kidney in nitrogen conservation in sheep on low dietary nitrogen intakes. Urea reabsorption from the distal tubules of nephrons and medullary collecting ducts is facilitated through changes in urea concentrations in the kidney tissue, accentuated by the counter-current multiplier system of vasa recta and the loop of Henle. It is believed that the same mechanism is operative in the water-deprived ruminant but experimental evidence is not yet available.

Conserved urea nitrogen is thus retained and returned to the blood. It is then recycled to the rumen via saliva and directly through the rumen wall (Houpt, 1959; Weston and Hogan, 1967; Vercoe, 1969). In the rumen recycled urea is partly utilized for microbial protein synthesis, thus adding to the efficiency of nitrogen utilization.

Preliminary experiments with sheep showed that there was an upper limit for the transfer of urea from blood across the rumen wall. These results were in agreement with those reported by Weston and Hogan (1967) in sheep, and by Vercoe (1969) in cattle. On the other hand, Houpt (1959) and Houpt and Houpt (1958) reported that urea transfer to the rumen was a direct function of the blood urea concentration.

Under present experimental conditions, the transfer of urea to the rumen was greater in camels than in sheep during both control and water deprivation periods; however, they had lower blood urea concentrations. Since rumen ammonia concentrations were also lower in the
camel, it may be possible that both the concentration of urea in blood, and of ammonia in the rumen contribute to greater transfer of urea across the rumen wall.

Furthermore, water deprivation decreased urea transfer in both animal species and camels still recycled more urea than sheep. Species differences in urea transfer are known to exist between sheep (Weston and Hogan, 1967) and cattle (Vercoe, 1969). Moreover, it may be that reduction in tissue fluids in water-deprived animals (Macfarlane et al., 1956) has influenced the rate of transfer across the rumen epithelium. Also, the increased concentration of rumen ammonia during water deprivation may have affected the entry rate of urea into the rumen.

Decreased recycling during water deprivation was not consistent with the improved overall nitrogen economy of the water-deprived animals observed in the present experiment. It appears that the role of the kidneys in nitrogen conservation was detrimental in this respect.

Water deprivation is not only beneficial to the nitrogen economy of ruminants, but it also improved energy utilization. Rogerson (1963) provided evidence that cattle on a low protein diet were able to maintain energy balance when subjected to moderate water deprivation. The rumen protozoal population was distinctly different in the two animals. That in the sheep belonged to the type A population, whereas the population in the camel was type B according to the classification of Eadie (1962). Furthermore, Epidenium was found in camels, but it was reported absent from Egyptian animals (Abou Akkada and El-Shazly, 1964; Naga et al., 1968). One cross-inoculation trial (Naga, unpublished) between a camel and a cow failed to establish Epidenium in the rumen of the cow.

Water deprivation reduced protozoal count in both camels and sheep. Entodenium, the dominant protozoan
in both species, decreased in sheep and increased in the camel. Holotricha counts were negatively correlated to water consumption. Further experiments are needed to investigate the rumen microbial population of camels.

Conclusion

The present results indicate that the camel is a better adapted animal than the sheep in terms of both water and nitrogen conservation and especially when exposed to conditions of combined water and nitrogen insufficiency. Further studies are needed to throw more light on the camel's potential as an economic grazing unit in arid and semi-arid rangelands.

Table 1: Average absolute and relative daily weight changes of camels and sheep fed a low-protein, roughage diet during periods of control and water deprivation.

<table>
<thead>
<tr>
<th>Control (59 days):</th>
<th>Sheep</th>
<th>Camels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial weight, kg</td>
<td>46.50</td>
<td>46.00</td>
</tr>
<tr>
<td>Average weight change, g/day</td>
<td>130</td>
<td>-140</td>
</tr>
<tr>
<td>Relative weight change, g/day/kg</td>
<td>-3.01</td>
<td>-3.29</td>
</tr>
<tr>
<td>Water deprivation (60 days)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial weight, kg</td>
<td>40.00</td>
<td>39.00</td>
</tr>
<tr>
<td>Average weight change, g/day</td>
<td>-133</td>
<td>-200</td>
</tr>
<tr>
<td>Relative weight change, g/day/kg</td>
<td>-3.70</td>
<td>-6.06</td>
</tr>
</tbody>
</table>
Table 2: Average daily free water intake and water excretion during the control and water deprivation treatments in camels and sheep.

<table>
<thead>
<tr>
<th></th>
<th>Sheep</th>
<th>Camels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intake</td>
<td>Faecal</td>
</tr>
<tr>
<td>Control period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ML/day</td>
<td>1828</td>
<td>428</td>
</tr>
<tr>
<td>ML/day kg(^{0.82})</td>
<td>90</td>
<td>21.1</td>
</tr>
<tr>
<td>Percent of intake</td>
<td>100</td>
<td>23.4</td>
</tr>
<tr>
<td>ML/g DM</td>
<td>4.24</td>
<td>1.38</td>
</tr>
<tr>
<td>Water deprivation period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ML/day</td>
<td>1326*</td>
<td>268</td>
</tr>
<tr>
<td>ML/day/kg(^{0.82})</td>
<td>85.2</td>
<td>17.1</td>
</tr>
<tr>
<td>Percent of intake</td>
<td>100</td>
<td>20.2</td>
</tr>
<tr>
<td>ML/g DM</td>
<td>2.38</td>
<td>1.02</td>
</tr>
</tbody>
</table>

* One-third and one-twelfth the amount drunk on watering days for sheep and camels respectively.
Table 3: The effect of water deprivation on dry matter intake, digestibility coefficients and TDN intake in camels and sheep.

<table>
<thead>
<tr>
<th></th>
<th>Sheep</th>
<th>Camels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Water depriv.</td>
</tr>
<tr>
<td>Dry matter, g/day/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>32.4</td>
<td>43.0</td>
</tr>
<tr>
<td>Digested</td>
<td>13.0</td>
<td>21.6</td>
</tr>
<tr>
<td>Apparent digestion coefficients, % dry matter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>40.38</td>
<td>51.31</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>54.36</td>
<td>58.30</td>
</tr>
<tr>
<td>Ether ext.</td>
<td>49.43</td>
<td>49.39</td>
</tr>
<tr>
<td>N. free ext.</td>
<td>37.65</td>
<td>65.88</td>
</tr>
<tr>
<td>TDN intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/day</td>
<td>177.4</td>
<td>249.4</td>
</tr>
<tr>
<td>g/day/kg 0.75</td>
<td>10.01</td>
<td>15.83</td>
</tr>
</tbody>
</table>

Table 4: Nitrogen balance of camels and sheep fed a low-protein roughage diet and the effect of intermittent water intake.

<table>
<thead>
<tr>
<th></th>
<th>Sheep</th>
<th>Camels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Water depriv.</td>
</tr>
<tr>
<td>Nitrogen balance data, mg N/day/kg 0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N intake</td>
<td>411</td>
<td>530</td>
</tr>
<tr>
<td>Faecal N</td>
<td>185</td>
<td>223</td>
</tr>
<tr>
<td>Digested N</td>
<td>226</td>
<td>307</td>
</tr>
<tr>
<td>Urinary N</td>
<td>407</td>
<td>359</td>
</tr>
<tr>
<td>Nitrogen balance</td>
<td>-181</td>
<td>-52</td>
</tr>
<tr>
<td>Relative nitrogen excretion, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faecal intake</td>
<td>46.3</td>
<td>41.6</td>
</tr>
<tr>
<td>Urinary/ digested</td>
<td>188.8</td>
<td>117.8</td>
</tr>
</tbody>
</table>
Table 5: Rumen fluid volume in camels and sheep watered intermittently.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Days of water deprivation</th>
<th>Hours after feeding</th>
<th>Rumen fluid volume 1. mL/kg(^{0.85}) mL/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camel</td>
<td>-</td>
<td>0</td>
<td>40.8</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2</td>
<td>62.8</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>6</td>
<td>53.8</td>
</tr>
<tr>
<td>Sheep</td>
<td>-</td>
<td>0</td>
<td>5.30</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2</td>
<td>7.33</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>6</td>
<td>6.22</td>
</tr>
<tr>
<td>Camel</td>
<td>w</td>
<td>6</td>
<td>70.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6</td>
<td>64.5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6</td>
<td>54.5</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6</td>
<td>48.7</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>6</td>
<td>39.2</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>6</td>
<td>29.4</td>
</tr>
<tr>
<td>Sheep</td>
<td>w</td>
<td>6</td>
<td>5.65</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6</td>
<td>4.17</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>2.96</td>
</tr>
</tbody>
</table>

Table 6: Volatile fatty acid concentrations in the rumens of camel and sheep watered intermittently (meq/100 mL)

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Sheep</th>
<th>Camel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours after feeding</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>I. Control</td>
<td>13.31</td>
<td>11.08</td>
</tr>
<tr>
<td>II. Water deprivation days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>19.91</td>
<td>16.79</td>
</tr>
<tr>
<td>3</td>
<td>18.88</td>
<td>13.10</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 7: Total volatile fatty acids in the rumens of camels and sheep watered intermittently.

<table>
<thead>
<tr>
<th>Days</th>
<th>Sheep Control</th>
<th>Sheep Water depriv.</th>
<th>Camels Control</th>
<th>Camels Water depriv.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m Equivalents¹:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w</td>
<td>772</td>
<td>913</td>
<td>5752</td>
<td>10425</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>709</td>
<td>-</td>
<td>11799</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>450</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8582</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9042</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7990</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4815</td>
</tr>
<tr>
<td>Average:²</td>
<td>772</td>
<td>691</td>
<td>5752</td>
<td>8458</td>
</tr>
<tr>
<td>Meq VFA/g TDN intake:</td>
<td>407</td>
<td>277</td>
<td>329</td>
<td>629</td>
</tr>
</tbody>
</table>

1) At 6 hours after feeding.
2) Averages weighted by extrapolation.

Table 8: Rumen ammonia nitrogen concentrations in camels and sheep watered intermittently (mg N/100 ml).

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Sheep</th>
<th>Camels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hours after feeding</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>I. Control period</td>
<td>6.72</td>
<td>7.56</td>
</tr>
<tr>
<td>II. Water deprivation</td>
<td>8.72</td>
<td>6.82</td>
</tr>
<tr>
<td>w</td>
<td>11.12</td>
<td>14.29</td>
</tr>
<tr>
<td>2</td>
<td>9.81</td>
<td>12.01</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 9: Blood urea nitrogen concentration in camels and sheep watered intermittently (mg N/100 ml).

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Treatment</th>
<th>Hours after feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>day 0 2 4 8 12</td>
</tr>
<tr>
<td>Sheep</td>
<td>Control</td>
<td>4.27 7.10 11.48 8.16</td>
</tr>
<tr>
<td></td>
<td>Water deprivation</td>
<td>14.42 17.40 18.29 17.26 9.24</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>15.50 18.32 16.56 11.28 10.38</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>15.80 14.19 12.13 13.73 6.46</td>
</tr>
<tr>
<td>Camel</td>
<td>Control</td>
<td>2.77 3.26 4.36 5.58</td>
</tr>
<tr>
<td></td>
<td>Water deprivation</td>
<td>8.60 7.94 7.35 8.60 6.74</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>12.60 11.29 7.53 4.71 2.05</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.49 8.56 12.72 8.68 4.71</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>13.85 10.77 12.12 8.89 3.27</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>16.12 9.23 5.56 5.84 7.12</td>
</tr>
</tbody>
</table>

Table 10: Estimated net urea transfer to the rumen in camels and sheep and the effect of water deprivation.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Day</th>
<th>Net recycling / day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>g N</td>
</tr>
<tr>
<td>Camels</td>
<td>C</td>
<td>23.35</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>26.97</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>13.26</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>5.57</td>
</tr>
<tr>
<td>Sheep</td>
<td>C</td>
<td>2.86</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.62</td>
</tr>
</tbody>
</table>
Table 11: Total and differential counts of rumen protozoa in camels and sheep and the effect of water deprivation.\(^a\)

<table>
<thead>
<tr>
<th>Animal</th>
<th>Sheep</th>
<th>Camels</th>
<th>Days</th>
<th>C</th>
<th>W</th>
<th>3</th>
<th>C</th>
<th>W</th>
<th>4</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total count per ml (X 10^6)</td>
<td>1.52</td>
<td>1.26</td>
<td>1.40</td>
<td>1.23</td>
<td>1.09</td>
<td>0.99</td>
<td>0.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total count per rumen (X 10^9)</td>
<td>9.6</td>
<td>9.1</td>
<td>3.3</td>
<td>53.0</td>
<td>85.0</td>
<td>53.9</td>
<td>32.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species percentages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entodinium</td>
<td>75.6</td>
<td>68.4</td>
<td>62.7</td>
<td>73.7</td>
<td>83.8</td>
<td>81.3</td>
<td>82.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epidenium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.9</td>
<td>4.8</td>
<td>3.9</td>
<td>7.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metadenium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.0</td>
<td>3.6</td>
<td>5.0</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eudiplodinium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13.5</td>
<td>7.9</td>
<td>9.7</td>
<td>10.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diplodinium</td>
<td>12.1</td>
<td>16.2</td>
<td>16.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophreoscolex</td>
<td>3.7</td>
<td>3.2</td>
<td>4.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astrochadenium</td>
<td>1.8</td>
<td>3.2</td>
<td>4.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyplastron</td>
<td>2.2</td>
<td>3.0</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holotricha sp.</td>
<td>4.2</td>
<td>9.1</td>
<td>8.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Counts were carried out in samples taken 6 hours after feeding.
Rumen ammonia
mg N per 100 ml

Figure 1: Effects of rates of intraruminal and intravenous infusion of urea on ruminal ammonia concentration between 12 and 24 hours after feeding in sheep (rates are in mg N/min).

Rumen ammonia
Mg N per 100 ml

Figure 2: Relationships between rumen ammonia concentration and urea infusion rates in sheep.
**Figure 3:** Schematic representation of the method used to estimate net urea transfer to the rumen.

Rumen volume

\[ \log_{10} \text{ml/kg}^{0.82} \]

**Figure 4:** Changes in rumen fluid volume associated with water deprivation in camels and sheep.
REFERENCES


Eadie, J.M. 1962 Inter-relationships between certain rumen ciliate protozoa. Journal of General Microbiology, 29:579


THE DIGESTIVE PHYSIOLOGY OF CAMELIDS

W. von Engelhardt, K. Rübsamen and R. Heller

Introduction

The two suborders of Artiodactyla (the Ruminantia and the Tylopoda) possesses the characteristics of rumination and forestomach digestion. Microbial digestion and biochemical processes in the capacious forestomachs of both families are similar. However, there exist morphological and functional differences. Attempts to homologize the different stomach regions of the Ruminantia and Tylopoda mostly have not been helpful.

The suborder Tylopoda has only one family, the Camelidae. The common origin of this suborder had developed in North America. The ancestors of our present Old World Camelidae had moved north to Asia, and those which migrated south developed into the New World Camelidae. There are many legends concerning the ability of the camel to survive dry conditions and periods when only food of poor quality is available. Water metabolism in camels has been extensively studied. However, little is known of the digestive functions in these animals. Some relevant information has been gained from studies on the gastro-intestinal tract in the closely related llama, and it is hoped that these findings will stimulate and encourage further studies on the digestive physiology in camels. The anatomy of the gastrointestinal tract in these two camelids is similar. Llamas and camels, however, live in different environments, and it must be assumed that the specific adaptations to the environment are different.

Gross morphology of the stomach

The forestomach of camels and llamas is divided into several compartments. There are controversial opinions
on the systematic position of the Tylopoda. One of the first descriptions of the camel stomach was given by Perrault (1666-1669) who noted that the stomach consists of four compartments and that the mucosa is different from the epithelium in ruminants. The first two compartments contain numerous saccules which previously were erroneously assumed to serve as water reservoirs during dehydration. From observations on the llama stomach, Brandt (1841) and Cordier (1894) suggested a similarity of the first compartment to the rumen, the second compartment to the reticulum and the third to the omasum. Cuvier (1805), Boas (1890), Hegazi (1950) and Purohit and Rathor (1962) considered that the third compartment consisted of omasal and abomasal portions. Hansen and Schmidt-Nielsen (1957), Bohlken (1960), Dellmann et al. (1968), Neurand et al. (1969) and Shahrasbi and Radmehr (1974) all used this terminology, although most of these workers realized that the stomachs in camelids are not similar to those of ruminants.

In more recent studies Vallenas et al. (1971) have described in detail the morphology of the New World camelid stomach. These authors state that the forestomach consists of three distinct compartments. The esophagus enters the first compartment which is divided ventrally by a transverse muscle pillar into a cranial and caudal sac. The second compartment is only partially separated from the first compartment and is relatively small. It is separated from the third compartment by a sphincter. The third compartment is an elongated tubiform organ slightly dilated in its proximal end. At the distal end contents enter into the hind stomach with fundic and pyloric glands.

The surface of most of the first and second compartments is lined with a nonpapillated, stratified-squamous epithelium. The ventral parts of compartment 1 and 2 and all the surface of compartment 3 are covered with a glandular epithelium. In the caudal sac of compartment 1 there are well-developed glandular pouches.
The total surface area of the first compartment measured in two adult llamas was about 6700 cm^2, half of it being accounted for by the sacculated glandular area of the caudal sac (Rübsamen, 1976). The surface area of this compartment in the camel is not known; Vallenas et al. (1971) mentioned that the glandular area in the first compartment of the camel may be relatively smaller due to smaller pouches, and in camels the glandular area is restricted to the bottom of the saccules (Hansen and Schmidt-Nielsen, 1957).

In the adult llama the contents in compartments 1 and 2 account for 10 to 15 percent of body weight, those of compartment 3 for 1 to 2 percent.

Histology and ultrastructure of the epithelium in the stomach

**Forestomach**

The epithelial cells of the forestomach have been described in camels by Hansen and Schmidt-Nielsen (1957), and Dellmann et al. (1968), and in llamas by Cummings et al. (1972), and Luciano et al. (1979). The stratified squamous epithelium in the llama was found to be unkeratinized (Luciano et al., 1979); the mucigenous glandular mucosa is similar in structure in all compartments of the forestomach (Cummings et al., 1972; Rübsamen, 1976; Luciano et al., 1979). Four regions could be distinguished in these glands; the luminal surface epithelium covering the ridges between different foveolae, the foveolar epithelium, the isthmic epithelium and the epithelium of the end-piece (Cummings et al., 1972). The luminal surface epithelium consists of tall, laterally compressed cells, containing mucous granules. The number of mucous granules becomes greater in cells situated close to the foveolar orifice, and they reach a maximum in the foveolar epithelium where nearly half of the cells consist of mucous granules. The granules are heavily stained by PAS, Alcian blue and Toluidin blue.
Electron microscopic studies revealed the presence of numerous apical microvilli as well as mucous granules which seem to be synthesized and secreted rapidly (Luciano et al., 1979). These mucus constituents were chemically identified as glycoproteins of different composition (Rübsamen, 1976).

The glands of the isthmus and end-piece epithelium are different in structure and function from that of surface and foveolar cells. There is evidence from numerous mitotic figures that the cells of the isthmus epithelium are involved in the renewal of the foveolar and surface epithelium (Cummings et al., 1972). The end-piece of the glands shows a slight apical accumulation of PAS-positive material. However, the reaction with Alcian blue and Toluidin blue differs from that found in the surface and foveolar epithelium. Furthermore, many endocrine cells are present in this area, as shown by electron-microscopy (Luciano et al., 1979) and the Falck-Hillarp technique (Rübsamen, 1976).

There is also little information on the function of this glandular epithelium in the camelid forestomach. Recent studies (Rübsamen and Engelhardt, 1979) show that the layer of mucus which covers the surface epithelium may have mainly protective functions. The suggested role of these glands as accessory salivary glands (Schmidt-Nielsen, 1964) seems to be insignificant; the mucous constituents have little buffering capacity, and bicarbonate secretion observed by Eckerlin and Stevens (1972) could not be seen in experiments in a Pavlov pouch in llamas (Rübsamen and Engelhardt, 1978). We assume that the main function of this glandular region in the forestomach of camelids is the rapid absorption of water and solutes. The presence of characteristic absorptive cells at the luminal surface (Cummings et al., 1972; Luciano et al., 1979) strongly suggests this specific task.
Hind stomach

The hind stomach is relatively small. In the llama it is less than one fifth of that of the tubiform compartment 3. Approximately half of the surface of the hind stomach is covered with fundic epithelium and the rest, toward the pylorus, with pyloric epithelium. The small size of the fundic region is surprising. However, these cells can effectively secrete HCl. The pH drops from about 6.5 in the anterior part of compartment 3 to values below 2 in the hind stomach. Mucous cells, parietal cells, chief cells and endocrine cells are similar to those in monogastric animals (Luciano et al., 1980). The fundic epithelium is thick, and the tubular gastric glands are long. Only limited data are available on the structure of the mucous membrane in camels. Light microscopic studies indicate that staining characteristics and structure are similar to that found in New World camelsids (Hansen and Schmidt-Nielsen, 1957; Dellmann et al., 1968; Chahrasbi and Radmehr, 1975). Further investigations especially on ultrastructure are necessary to establish this point.

Motility of the llama forestomach

The motility characteristics in camelids are very different from those in the reticulorumen of ruminants. All findings so far known are gained from experiments with the New World camel; there are no data available about forestomach motility in camels. (See appendix.)

Compartment 1 and 2

Each motility cycle starts with one strong contraction in the canal between compartments 2 and 3. After the contraction of the canal there is always a single rapid contraction of compartment 2. During this contraction the canal relaxes, and the pressure values fall below the baseline; after that the canal contracts a second time. Following the contraction in compartment 2 the caudal sac of compartment 1 contracts (Heller et al.,
in press). Ehrlein and Engelhardt (1971) in their studies with the guanaco always observed contractions of the caudoventral region prior to the caudodorsal part; Vallenas and Stevens (1971 b) described a simultaneous contraction of both these regions in alpacas. After contraction of the caudal sac the cranial sac contracts accompanied by a weak canal contraction, followed by contractions of compartment 2, caudal sac and cranial sac. This sequence is repeated several times. The duration of a cycle was $1.4 \pm 0.4$ min. in the resting llama; the rate increased during feeding.

We distinguish between (a) the number of contractions in one cycle and (b) the frequency of cycles. Distension of the cranial sac, or the canal, or the proximal compartment 3 increased the number of contractions in a cycle and decreased the frequency of cycles. Distension of the distal section of compartment 3 decreased the number of contractions per cycle and increased the frequency of cycles (Gregory and Heller, unpublished). Ehrlein and Engelhardt (1968, 1971) mentioned that a new cycle always started with a contraction of compartment 2; these contractions became weaker toward the end of each cycle. Vallenas and Stevens (1971 b), on the other hand, recorded compartment 2 contractions only once preceding the first set of a cycle. Neither of these groups recorded motility in the canal.

During contraction of compartment 2 the contents are pumped from compartment 2 into the caudal sac of the first compartment. When the caudal sac contracts, contents are partly directed into compartment 2 and partly into the cranial sac. Finally, during cranial sac contraction, the contents are transferred back into the caudal sac (Ehrlein and Engelhardt, 1968).

The contents in the dorsal portion of the first compartment are rather dry. The ventral region of the cranial sac, glandular sacs as well as compartment 2, contain semifluid and watery ingesta (Ehrlein and
Engelhardt, 1968, 1971; Vallenas and Stevens, 1971 b). Observations via a fistula in the left flank show that contents in the caudal sac of compartment 1 rotate slowly counter-clockwise. The strong contractions squeeze out fluid, and semifluid ingesta exchanges with that in the glandular region where most of the absorption takes place.

Compartment 3
In x-ray studies and recordings with balloons in compartment 3 of the llama circular constrictions, mostly occurring simultaneously at different areas along compartment 3, where seen (Ehrlein and Engelhardt, 1971; Heller, unpublished). The term "peristaltic" used for these contractions by Ehrlein and Engelhardt may not be justified for the proximal part; motility in the distal region seems to be peristaltic (Heller, unpublished). In the proximal part of compartment 3 circular constrictions (10 min⁻¹) are weak, in the distal section pronounced contractions (5 min⁻¹) are seen and recorded (Ehrlein and Engelhardt, 1971; Heller, unpublished). Motility of compartment 3 is directed aborally; no reflux between the fundic region and compartment 3 was ever observed.

The contents in compartment 3 are rather dry. This is partly due to an extensive absorption of water (Engelhardt et al., 1979); fluid also may be squeezed out towards the pylorus.

Flow of digesta and mean retention time
Although the canal between compartments 2 and 3 of the llama is not contracted for most of the time, contents pass only when the canal is dilated during the first strong contraction of compartment 2 in a motility cycle. After that the proximal part of the canal contracts and the distal part dilates, followed by a contraction of the whole canal whereby the content is pumped into com-
partment 3. Ingesta transfer from compartment 2 to 3 may be similar to that into the omasum of ruminants (Stevens et al., 1960; Ehrlein and Hill, 1969). The flow rate of fluid from compartment 2 into 3 of a llama weighing 120 kg was approximately 850 ml/h; with each motility wave in the canal about 17 ml fluid passed into compartment 3 (Engelhardt et al., 1979).

Mean retention time of fluid in the forestomach of the llama was 9.6 hrs in compartments 1 and 2, and 5.7 hrs in compartment 3. Hay particles with a length of 0.2 cm had a mean retention time of 20.3 hrs in compartments 1 and 2, and 9.0 hrs in compartment 3. Thus, mean retention time of fluid in compartments 1 and 2 and in compartment 3 is considerably less than that of solid particles. The retention time of particles depends on their size; larger particles were retained in compartments 1 - 3 up to 40 hrs (Heller, unpublished).

Rumination and eructation in the llama

Regurgitation occurs at the maximum of the contraction of the cranial sac of compartment 1. It may occur 3 to 4 times per cycle, when contents in the cranial sac are lifted up to the cardia; contractions of the second compartment of the forestomach were completely unrelated to regurgitation (Ehrlein and Engelhardt, 1971; Vallenas and Stevens, 1971 b).

Eructation was always observed near the peak of the caudal sac contraction when gas is pressed toward the oesophagus; eructation may take place 3 to 4 times per cycle (Ehrlein and Engelhardt, 1971; Vallenas and Stevens, 1971 b). Total amounts of gas eructed on a weight basis were comparable to results obtained in similar studies in cattle (Dougherty and Vallenas, 1968).
Salivary secretion

Salivary glands in camels and llamas appear similar in size and histology (van Lennep, 1957; Hoppe et al., 1975; Nawar and El-Khaligi, 1977). As in ruminants the parotid glands are purely serous. Most other salivary glands are mucous and serous. Some of the smaller glands seem to be purely mucous (van Lennep, 1957; Hoppe et al., 1975) though there might have been some difficulty in identifying the smaller glands. In all respects salivary glands in camelids are similar to those of cattle, sheep and goats.

The parotid saliva of the camel (Hoppe et al., 1975) as well as parotid and mixed saliva of the llama (Engelhardt and Sallmann, 1972; Ortiz et al., 1974; Hinderer, 1978) showed the rapid flow and alkaline reaction as measured in ruminants. Saliva in camelids is hypotonic, the bicarbonate concentration being high. In camels dehydrated to a 25 percent loss of body weight, the parotid salivary flow was only one fifth that of hydrated animals (Hoppe et al., 1975). In mixed saliva of camels a slight amylolytic activity was observed (Nasr, 1959).

Digestion in camelids

Williams (1963) observed a high concentration of short chain fatty acids (VFA) in the relatively dry contents of the first compartment in camels. The proportions of VFA were similar to those found in rumen contents of ruminants. Similar results were obtained by Malooy (1972) comparing digestion and fermentation in the forestomach of camel and zebu steer. Fermentation rates measured in vitro and the pH were similar; a slightly higher VFA concentration was observed in the camel.

Although VFA concentrations do not allow quantitative estimations of VFA production these values indicate no major differences in the metabolism in the forestomach
contents in camelids and ruminants. The marked differences in morphology and structure obviously do not notably influence fermentation rate as was revealed in earlier in vitro studies. Fluid outflow from the forestomach and passage of food through the gut was reported to be higher in the camel than in the zebu steer; this might have been the reason for the observed lower efficiency in camels in digesting the dry matter of low quality hay (Maloiy, 1972). In llamas fed a medium quality hay digestibility was not significantly different from that in sheep. When food intake was reduced in these llamas energy metabolism on the basis of metabolic body weight was reduced to values below those expected for mammals (Engelhardt and Schneider, 1977).

Absorption and secretion in the forestomach

Absorption and secretion in the different compartments of the forestomach has been studied only in the New World camelids. Eckerlin and Stevens (1972) suggested a significant contribution of the glandular sacculles to buffering capacity of forestomach contents. When the isolated second compartment was filled with isotonic NaCl solution a considerable portion of Cl⁻ was lost and HCO₃⁻ was gained within one hour, while Na⁺ and K⁺ levels were not markedly affected. There is evidence from studies in the Pavlov pouch in the glandular region of compartment 1 in the llama (Rübsamen and Engelhardt, 1978) that the bicarbonate secretion described by Eckerlin and Stevens (1972) may be a result of rather unphysiological conditions. Using solutions similar in ionic composition to that of normal forestomach contents, only 0.4 mmol · h⁻¹ bicarbonate accumulated, while VFA and Cl⁻ disappeared rapidly. The net bicarbonate gain was mainly affected by the pH of the solution added into the pouch. In the absence of VFA bicarbonate accumulation was significantly lower. It may be assumed that the appearance of bicarbonate may be linked to the absorption of VFA. The nonionic absorption of VFA requires equimolar amounts
of $H^+$ ions, which can be delivered from the dissociation of $H_2CO_3$ formed in the presence of carbonic anhydrase from $CO_2$, diffusing across the forestomach wall or gained from metabolism in forestomach contents. The interrelationship between VFA absorption, bicarbonate appearance, and $H^+$ ion concentration indicates that under physiological conditions the gain of $H^+$ ions from $H_2CO_3$ is not of importance; it becomes significant only at alkaline pH values in forestomach contents. In normal forestomach contents $pCO_2$ is high, and thus bicarbonate gain depends mainly on $H^+$ loss.

VFA, sodium, and chloride are rapidly absorbed from the temporarily isolated first compartment of the forestomach in the llama (Engelhardt and Sallmann, 1972). These findings were confirmed in Pavlov pouch experiments (Rübsamen and Engelhardt, 1979). Absorption rates were about 2 - 3 times those in the rumen of sheep and goats. These pouch experiments illustrated that the high absorption rates occur mainly in the glandular area of the forestomach. The ultrastructure indicates a high absorptive capacity of the surface epithelial cells in the glandular region; the stratified squamous epithelium, on the other hand, has a relatively small surface because no papillae are developed. Rapid absorption is facilitated by a periodic prolapse of the glandular saccules, which achieves a rapid change of the fluid inside the saccules.

In the third compartment of the llama forestomach solutes and water are rapidly absorbed (Engelhardt et al., 1979). This was expected from the structure of the glandular epithelium lining this tubiform section of the forestomach. Sixty percent sodium, 70 percent VFA, and 30 percent water entering this compartment were absorbed during its passage. Considering the different body size, the absorption rates in this tubiform forestomach are significantly higher than those measured in the omasum of sheep and goats (Engelhardt and Hauffe, 1975).
No information is available on absorption and secretion in the camel forestomach. Similarities in morphology may indicate similar absorptive and secretory processes.

Secretion in the hind stomach

In one llama with a cannula in the distal part of compartment 3 samples were regularly contaminated with contents from the hind stomach (Engelhardt et al., 1979). Analyses showed that intensive acidification occurs in the short hind stomach. Chloride concentration was high, pH was low, and the amount of water secreted was 50 percent higher than that absorbed in the preceding tubiform compartment 3.

Adaptation to low protein diets

Camels, especially during drought conditions, often have access only to roughage of a low crude protein content. Schmidt-Nielsen et al. (1957) showed that pregnant camels on a low protein diet excrete only little urea with urine. It was therefore assumed that on a low protein diet, urea enters the forestomach where it is used for the synthesis of protein (Schmidt-Nielsen, 1964).

Urea recycling

Urea recycling to the gastrointestinal tract can be high in camelids on a low protein diet. The extent of recycling increased from 47 percent to 86 percent of total urea turnover when the dietary protein content in camels decreased from 13.6 to 6.1 percent (Emmanuel et al., 1976). Ali, Hirghani and Hume (unpublished) have recently found that camels fed a low (c. 3 percent) crude protein diet of dry desert grass recycled 92 percent of endogenous urea. In llamas fed a low protein diet supplemented with sufficient energy the recycling
rate was between 91 percent and 95 percent (Ali et al., 1977; Hinderer, 1978). If the recycled urea-N cannot be utilized for microbial protein synthesis ammonia-N will be reabsorbed into the blood. This would be a futile circulation of urea nitrogen.

Utilization of endogenous urea-N
Utilization of urea-N can be estimated quantitatively by using $^{15}$N-labelled urea. In the llama 13.6 mmol urea N/h or 78 percent of the recycled endogenous urea-N was utilized on a low protein diet with sufficient energy content, compared with 2.0 mmol urea-N/h or 10 percent on a control diet (approximately maintenance requirements and isocaloric to the low protein diet), and 11.8 mmol urea-N/h or 34 percent in a low protein, low energy, high crude fibre diet (Ali et al., 1977; Hinderer, 1978). The amount of urea-N utilized as a percentage of N-intake was 6 percent for the control diet, 38 percent for the isocaloric, low protein diet, and 48 percent for the low protein, high crude fibre diet.

Factors affecting recycling of urea-N
In llamas eight different diets with rather low protein and varying energy contents were fed. It became evident that plasma urea concentration had little influence on the amount of urea recycled into the gastrointestinal tract (Hinderer and Engelhardt, 1976; Hinderer, 1978). From these studies it is obvious that the permeability of the gastrointestinal epithelium to urea changes with dietary conditions. The energy content of food and/or the low protein conditions appeared to be important factors in the change of the permeability (Engelhardt, 1978 b).

In ruminants and in camelids most of the utilization of endogenous urea-N occurs in the forestomach. Thus, it is important to know what portion of recycled urea passed into the forestomach, and which factors
influence this influx. In llamas fed hay ad lib. endo-
genous urea-N secretion into compartment 1 and 2 of the
forestomach was 52 percent of the urea recycled into
the total gastrointestinal tract; one fifth entered with
saliva, and the remainder diffused across the fore-
 stomach wall. When food was withheld for 48 hours the
plasma urea concentration increased. Despite the higher
concentration the influx of urea across the forestomach
wall decreased due to a lower permeability of the rumen
epithelium (Hinderer, 1978).

Metabolites in the forestomach affect the perme-
ability of the forestomach epithelium to urea in the
llama as well as in ruminants. Both volatile fatty
acids and CO₂ increase the permeability considerably
butyric acid having a stronger effect than acetic or
propionic acid. With an increase in butyric acid con-
centration from 5 to 40 mmol/l in the temporarily
isolated compartment 1 and 2 the urea influx into the
forestomach of the llama was doubled. The strongest
effect was seen when the solution in the forestomach
was continuously gassed with CO₂; the permeability was
increased nearly fourfold. Increasing the ammonia con-
centration is a powerful means of decreasing the perme-
ability of the forestomach wall as was shown by Engel-
hardt (1978 b).

Regulation of urea recycling can be important
especially during adaptation to low protein food. If
sufficient energy is available for rapid microbial
growth CO₂ production as well as high concentrations
of volatile fatty acids stimulate recycling of urea-N
considerably. At high microbial growth rates utilization
of recycled urea-N can be substantial, and incorporation
of urea-N into microbial protein can be of considerable
consequence for the protein gain of the host animal.

Renal nitrogen saving in animals fed low protein diets
For the most part mammals decrease renal urea excretion
when protein intake is low. It has been shown that this
low renal urea excretion is mainly due to a high tubular reabsorption of urea. In camels, llamas, sheep and goats on a low protein diet more than 95 percent of the glomerular filtered urea can be absorbed, and little urea is excreted (Schmidt-Nielsen, 1964; Engelhardt, 1978 a). These observations pointed to an adaptation in the kidney designed to conserve urea when availability of protein is limited. It was suggested that this renal urea saving forms an integral part of the nitrogen recycling mechanism.

However, results reported on renal urea excretion in ruminants as well as in camelids on low protein diets are conflicting. Similar contradictory results were obtained in experiments with llamas on low protein diets. For instance, when food intake was reduced, or when a straw diet was given, renal urea excretion was only slightly diminished, glomerular filtration rate was significantly reduced by about 35 percent but, due to a somewhat increased plasma urea concentration, the amount of urea excreted did not change compared to control experiments (Engelhardt and Engelhardt, 1976). However, when a low protein food isocaloric to the control diet was fed the expected high tubular reabsorption (94 percent of filtered urea) occurred; glomerular filtration rate was reduced by 35 percent, and plasma urea concentration was about 60 percent below that of animals on the control diet. These three factors together led to a low urea excretion in urine; the amount excreted was only 6 percent of that excreted during control experiments.

Another low protein diet fed to the llamas was also low in digestible energy, since the crude fibre content (straw) was increased. At first nothing happened but, after an adaptation period of ten weeks, tubular reabsorption increased, and 84 percent of glomerular filtered urea was reabsorbed (Engelhardt, 1978 a).

From these experiments and from the conflicting data in the literature it is concluded that; (1) it
is apparent that urea excretion in ruminating animals is not always a function of dietary protein content; tubular reabsorption of urea as well as the blood urea concentration depend mainly on the amount and the quality of energy available in the low protein food; (2) on a low protein, low energy diet with a high crude fibre content a rather long adaptation period is needed for developing high tubular reabsorption of urea; (3) on low protein diets with sufficient energy for microbial growth decreased plasma urea concentration and lowered glomerular filtration rate act together with a high tubular reabsorption of urea in achieving low renal nitrogen excretion.

Conclusions

The anatomy of the forestomach in Camelidae is distinctly different from that of Ruminantia. Motility characteristics are dissimilar. The timing of rumination and eructation in the course of the motility cycle differs from those of the reticulo-rumen of ruminants.

The sequence of contractions facilitates an effective microbial digestion of the rather dry forestomach contents, a long variable retention time of particles and the squeeze-off of water and solutes. The ultrastructure of the luminal surface epithelial cells in the mucigenous glandular mucosa show the attributes of characteristic absorptive cells. Absorption of solutes and water is rapid in this glandular region.

The stratified squamous epithelium that lines most of the first and second compartments of the forestomach has no papillae, thus the absorptive surface in these areas is small.

The function of the numerous endocrine cells in the stomach wall is unknown. They may play an important role during adaptation to extreme environmental conditions.
Microbial digestion, size and structure of salivary glands, and flow and composition of saliva are similar to those of ruminants.

Utilization of endogenous urea-N can be of considerable importance. Secretion of endogenous urea into the forestomach can be altered advantageously; it is high under conditions of high microbial growth rates, but it is diminished at high ammonia concentrations and low microbial digestion.

Our knowledge of the digestive physiology of camels is fragmentary. Camelids are able to adapt to some extreme conditions better than most other large herbivores. We should be able to intensify the use of camelids considerably if we understood the mechanisms involved in such fascinating adaptations, and if we know the minimum requirements and the limiting factors in such an extreme environment. Areas so far little used for animal production and settlement could be better utilized. The more extensive use of camels in such regions may reduce erosion.

APPENDIX

Motility of the forestomachs of the guanaco (Lama guanicoe).

H.-J. Ehrlein and W. von Engelhardt

In order to study the motility of the forestomachs, a fistula was prepared in the caudal sac of the first compartment in a guanaco. Contractions of the various

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1) Film W 935, Institut für den Wissenschaftlichen Film, D-3400 Göttingen, Nonnenstieg 72, Federal Republic of Germany.
parts of the forestomachs were recorded with balloons and Marey's capsules. After removal of the contents the movements of the forestomachs were observed and filmed through the fistula. At first the anatomical structure of the forestomachs is shown. The first compartment is divided into a cranial sac and a caudal sac by a strong transverse muscular pillar. The rib-like muscular bands, the glandular pouch area of the caudal sac, the horizontal muscular band of the cranial sac, the cardia at the upper part of the cranial sac and the second compartment at the aboral site of the transverse pillar can be seen.

The movements of the forestomachs start with a contraction of the second compartment (lasting 2-3 seconds). Contractions of the saccules in the caudal sac (lasting 2-3 seconds) and of the caudal sac of the first compartment (lasting 4-7 seconds) follow. At last the cranial sac contracts (lasting 4-7 seconds). This cycle of contractions (lasting 9-11 seconds) is repeated several times without pause. During the first cycle the contraction of the second compartment is stronger compared to the following cycles. After five to seven cycles a short break occurs, and the next period of contractions starts again with a strong contraction of the second compartment.

When the animal is fed with hay and concentrates, the digesta in the upper part of the first compartment are rather solid. Fluid digesta is present in the saccules of the caudal sac, in the ventral part of the cranial sac and in the second compartment. During the contractions of the first compartment, the solid contents are squeezed and slowly rotated. When the forestomach is emptied and partly filled with saline solution, movements of the first and second compartment and flow of liquid can be observed. During the contraction of the second compartment the fluid contents are forced into the caudal sac. By the following contraction the glandular pouches are prolapsed and become visible between the rib-like muscular bands. The fluid contents of the glandular
pouches are totally emptied; the liquid returned into the saccules during relaxation. During contraction of the caudal sac liquid is forced across the transverse pillar into the cranial sac. During the following contraction of the cranial sac, the horizontal muscular band contracts and moves ventrally. Thereby the lumen of the cranial sac is diminished and liquid is transferred into the caudal sac and into the second compartment. The sequence of contractions is shown in a smoke-drum recording.

REFERENCES


Hoppe, P., Kay, R.N.B., and Maloey, G.M.W., 1975. Salivary secretion on the camel. J.Physiol. 244, 32P-33P.


Maloey, G.M.O. 1972 Comparative studies on digestion and fermentation rate in the forestomach of the one-humped camel (Camelus dromedarius) and the zebu steer. Res.Vet.Sci. 13, 476-481.


CAMEL HUSBANDRY IN KENYA: INCREASING THE PRODUCTIVITY OF RANCHLAND

J.O. Evans and J.G. Powys

Summary

Camels have proved to be complementary to other livestock in four Kenya ranching operations, having different and more versatile feeding habits. They have adapted well to changes of habitat and suffered from few ailments. Management is comparatively cheap and easy. The main drawback is the slow rate of reproduction. They show economic promise, which should appreciate with improved breeding. They are intelligent and pleasant animals to work with.

Introduction

As Kenya ranchers, the authors of this paper have always sought to obtain maximum production from their land. Several years ago it became apparent to both that camels might contribute to this aim. Initial results and impressions are reported herewith.

Situation

Camels were introduced to four ranches between 1974 and 1978 whose locations are indicated in Fig. 1. They are:

(i) Galana Ranch (> 400 000 ha) which is south of the equator in the hinterland of the Kenya coast. It lies on the fringe of the coastal rainbelt in semi-arid savannah at an altitude of 270 m. a.s.l. and receives an average rainfall of 550 mm. Tsetse fly (Glossina spp.) and trypanosomiasis occur on parts of the ranch.
Figure 1: Map of Kenya to show location of ranches and sources from which camels were obtained.
(ii) Ol Maisor, Kisima and Ngare Ndare which lie just north of the equator in Kenya's Laikipia district at altitudes of between 1730 and 1890 m. a.s.l. All three ranches comprise approx. 12140 ha and receive an annual average rainfall of 580 mm.

Vegetation

The vegetation on the Galana ranch is influenced by a declining rainfall from east to west. In the extreme east there is thick coastal bush and forest containing *Afzelia quanzensis; Brachystegia spiciformis* and *Bombax rhodognaphalon*. This merges into light *Diospyros mespiliformis* parkland which in turn gives way to *Acacia* and *Commiphora* woodland. In the westernmost and lowest rainfall zone, Commiphorae dominate. In all zones there is extensive open grassland characterized by *Chloris* spp., *Shoenfeldia transiens* and *Aristida* spp. among a wide range of other species.

The other three ranches – Ol Maisor, Kisima and Ngare Ndare – have predominantly *Themeda*, *Setaria*, *Hyparrhenia*, *Loudetia* and *Cynodon* grasslands, scattered widely with *Acacia seyal*, *A. gerrardii* and *A. drepanolobium*. Bush and thicket containing *Euclea*, *Rhus*, *Grewia* and *Acacia brevispica* is also widespread.

Livestock

All four ranches carry Boran cattle stocked at 4–6 ha per beast, Merino or Merino x Dorper sheep stocked at 1–3 per head of cattle (with which they compete for grazing), and indigenous goats x exotic male introductions. The goats browse on low and medium sized bushes, controlling these and opening them up to permit the growth of grass which would otherwise be shaded out. Their small size limits their effect on the larger trees.
Introduction of camels

In 1974, 30 camels were purchased in the Wajir and Garba Tula districts of northern Kenya (Fig. 1) and walked to the Galana Ranch. In 1975 a further 100 females were acquired in Moyale (Fig. 1) of which 70 were moved to Galana and 30 to Ngare Ndare. Between 1975 and 1977 a number of camels were bought from the Turkana and Pokot people of the Rift Valley (Fig. 1) and moved to Ol Maisor, where they now number 102. In 1978 twenty females and a few males were bought in northern Wajir district and trekked to Kisima. Four commercial camel herds have thus been established.

The purposes of acquiring camels were essentially experimental but with the following in mind:

(i) by taking a spectrum of vegetation not used by the other domesticants, they would increase the productivity of all four ranches;

(ii) by eating many plants which grow among grass but are ignored by cattle, sheep and goats, the camels would improve the pasture for the other animals;

(iii) by providing milk for herdsmen normally dependent on a supply from ranch beef cows, beef calves would not be deprived and would show better growth;

(iv) by providing transport, camels would be an economic substitute for other forms in moving herdsmen's chattels, rations and equipment, enabling the cattle herds to make best use of available grazing (particularly on Galana);

(v) to establish a base from which to explore and, later, exploit an increasing demand for camel meat in certain Kenya towns, and the market for live camels in Arab states;
(vi) to establish a base upon which to develop a wider trade in camels from Kenya's stock of more than 600 000; and

(vii) to explore the possibilities of making camel milk cheese and the use of camel wool.

Management and adaptability

The camels are herded during the day and penned in thorn enclosures (bomas or zaribas) at night. These enclosures are in close proximity to others holding cattle, sheep and goats. Their use is primarily as protection against predators and thieves. They are moved to new locations every few weeks.

The camels withstood the transfer from low altitudes and very arid climates to the high altitudes and slightly wetter conditions of Ol Maisor, Kisima and Ngare Ndare. Some were in poor condition on arrival, but thrived and improved in condition rapidly.

They are provided with a mixed mineral lick containing phosphate, calcium, salt and trace elements for which they show greater appetite than cattle. These minerals are thought to be responsible for a better bone structure apparent in the young animals grown on the ranches.

The Somali camels from Wajir, Moyale and Garba Tula were tame and tractable. Those from Turkana and Pokot in the Rift Valley were nervous, headshy and inclined to kick. Gentle handling and kindness changed this and they are now docile and easily managed.

Several males and some females were trained for riding and baggage transport. This was easy and accomplished more quickly than would have been the case with horses. They show strong individual character and are very pleasant animals to work with.
Reproduction and lactation

Maturity has been reached at between six and eight years. Data from eleven females on the Ngare Ndare ranch are presented in Table 1 and show an average calving interval of 22 months (range 14-26 months), if the young survive.

Table 1: Calving records at Ngare Ndare ranch

<table>
<thead>
<tr>
<th>Camel No.</th>
<th>Calf sex</th>
<th>Birth date</th>
<th>Interval</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>M</td>
<td>15 12 76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>15 8 78</td>
<td>20 months</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>16 4 77</td>
<td></td>
<td>Died?</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>6 10 78</td>
<td>18 months</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>9 5 77</td>
<td></td>
<td>Killed by lion</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>10 4 79</td>
<td>23 months</td>
<td>Suckled other calf.</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>24 5 77</td>
<td></td>
<td>Died 5 6 77</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>10 7 78</td>
<td>14 months</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>9 5 77</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>14 7 79</td>
<td>26 months</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>19 12 77</td>
<td></td>
<td>Died?</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>18 7 79</td>
<td>20 months</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>10 4 78</td>
<td></td>
<td>Died</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>10 6 79</td>
<td>14 months</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>20 11 77</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>M</td>
<td>5 10 79</td>
<td>23 months</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>26 11 77</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>21 9 79</td>
<td>22 months</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>20 11 77</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>23 7 79</td>
<td>20 months</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>M</td>
<td>30 1 78</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>15 10 79</td>
<td>20 months</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Milk yields – Ngare Ndare herd. Morning milking records only; conditions very dry. (Litres)

<table>
<thead>
<tr>
<th>Camel No.</th>
<th>Date calved</th>
<th>10th Aug</th>
<th>29th Sept</th>
<th>28th Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6 10 78</td>
<td>1.13</td>
<td>1.70</td>
<td>Dry</td>
</tr>
<tr>
<td>6</td>
<td>3 4 79</td>
<td>3.40</td>
<td>3.40</td>
<td>3.97</td>
</tr>
<tr>
<td>13</td>
<td>10 6 79</td>
<td>3.12</td>
<td>3.69</td>
<td>3.40</td>
</tr>
<tr>
<td>26</td>
<td>27 6 79</td>
<td>1.98</td>
<td>2.27</td>
<td>2.55</td>
</tr>
<tr>
<td>10</td>
<td>14 7 79</td>
<td>7.00</td>
<td>4.26</td>
<td>4.54</td>
</tr>
<tr>
<td>12</td>
<td>15 7 79</td>
<td>2.27</td>
<td>2.84</td>
<td>4.54</td>
</tr>
<tr>
<td>20</td>
<td>23 7 79</td>
<td>2.27</td>
<td>2.84</td>
<td>3.40</td>
</tr>
<tr>
<td>27</td>
<td>18 9 79</td>
<td></td>
<td>3.40</td>
<td>3.40</td>
</tr>
<tr>
<td>15</td>
<td>21 9 79</td>
<td></td>
<td>3.40</td>
<td>4.54</td>
</tr>
</tbody>
</table>

Table 3: Milk yields – Galana herd. Comparison of milk records from 4 females milked 4 times a day, and twice a day.

<table>
<thead>
<tr>
<th>Camel No.</th>
<th>6 am</th>
<th>11 am</th>
<th>3 pm</th>
<th>6 pm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td>7.5</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>66</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

Average daily milk record, morning and evening milking only (litres).

<table>
<thead>
<tr>
<th>Camel No.</th>
<th>am</th>
<th>pm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>3.5</td>
<td>3</td>
<td>6.5</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>2.5</td>
<td>5.5</td>
</tr>
<tr>
<td>66</td>
<td>3.5</td>
<td>2</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Oestrus has occurred at 4.5 - 10 months post-partum and, in one instance in which there was a defective udder, 28 days.

Three gestations were recorded accurately; 2 male calves at 373 days, and 1 female calf at 393 days.
The young commence browsing at 1 month old if the females have little milk, but later at 2 months if milk is abundant.

In Tables 2 and 3 some data on milk yields are presented from Ngare Ndare and Galana ranches. Though scanty, they illustrate a potential which is within the range of that recorded by Knoess (1977) from the Awash Valley, Ethiopia.

Veterinary notes

Deaths have occurred from trypanosomiasis, pneumonia and hydatidosis in Turkana and Pokot camels, all contracted before purchase. Since purchase they have suffered from foot abscesses, Corynebacterium abscesses, joint ill (1 calf on Ol Maisor), eye infections, mange and (on Galana) trypanosomiasis.

Off-colour animals treated with tetracyclín and compound antibiotics have responded well.

Although worm egg counts are not necessarily indicative of a serious problem with internal parasites, animals have been dosed with nilverm, nilverm injectable, panacur, nemafax, thibenzole and neguvon injectable, with positive results.

The Galana animals are kept under prophylactic cover for trypanosomiasis with apparent success, by using antricyde sulphate and antricyde prosalt (both drugs now no longer available).

All animals have been vaccinated against black-quarter and anthrax.

The umbilical cords of new-born calves are tied with iodine-dipped ligatures against infection with joint-ill.
Mange has been serious in wet weather. Treatment with BHC and alugan have been moderately successful but delnav (organophosphorous) appears to be most effective. A rubbing-post draped with sackcloth soaked in old engine oil with delnav added, provides a useful method of administration.

Brucellosis appears to be prevalent in the Galana herd. Extensive tests were carried out recently by the Kenya Veterinary Department. The tests were not conclusive, and it would appear to be very difficult to isolate Brucella organisms in camels in the absence of freshly aborted foetuses. Thirteen blood samples taken in April 1978 from Ol Maisor females, were negative.

An attempt was made to infect two camels at Ngare Ndare with *Theleria lawrencii* (corridor disease). The serum was negative for antibodies and it was presumed camels are not susceptible to this disease, Johne's disease was isolated in serological tests on Galana but did not appear to cause a problem.

Foot abscesses and abscesses at the base of the neck and on the rump cause considerable distress. Abscesses in the gland can become large and require to be removed surgically. Pus from an abscess in one animal revealed *Corynebacterium pseudotuberculosis* and from another animal B-hemolytic streptococci.

A virulent outbreak of foot-and-mouth disease, type S.A.T. 2, in cattle, sheep and goats on Ol Maisor, with which the camels were in close contact, left them unaffected.

The breeding herd on Galana took two years to acclimatize and commence breeding regularly. When first introduced to the area they were not given any prophylaxis treatment for trypanosomiasis for over a year. Abortions and premature births were common, also a great many females were unable to feed their calves.
Since they have been injected regularly with
anticycide sulphate, the health and production of the
herd have improved dramatically.

Economics

While the price of camels is comparable to that of
good quality cattle, the distance from the ranches at
which they have had to be purchased has made their
acquisition very costly.

Direct expenses incurred in their upkeep have
proved less than those for our cattle (Ksh 70/- to
80/- p.a. without overheads). This is mainly because
they have not needed the regular and obligatory dipping
or spraying required by cattle to protect them from the
ticks and tick-borne diseases to which they are prone.

The slow reproductive rate of 22 months compared
to less than 14 months for ranch cattle, and slow matu-
ring rate of 6-8 years against 3-4 years for finished
steers, indicates a poor economic potential.

The return from camels might be improved with
experience and improved husbandry. It should be possible
to reduce the calving interval to 18 months (Knoess,
1976). Milk production might also be taken into account.

Even with such improvements, cattle will remain
the more profitable animals. However, we must emphasise
that our camel productivity is additional to and in no
way competitive with our beef production or any other
livestock on the property.

We have every hope that the quality of our camel
stock will improve, as our foundation animals tended to
be culls which the sellers thought to be defective.
It might speed up growth and individual quality if young
animals could be weaned and hand fed (the Turkana say
that they rear camel calves successfully on cow's milk).
When purchasing stock it is advisable to try and buy unbred females. Also to avoid buying heavily branded animals as this is generally an indication of some defect or illness. The pastoral people of Kenya use the practice of firing for almost any ailment.

Acknowledgements

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REFERENCE

SECTION D

CAMEL REPRODUCTION
SUMMARY OF STUDIES ON REPRODUCTION IN THE DROMEDARY

B.E. Musa

The oestrous cycle of the camel

There are differences of opinion among investigators concerning the nature of the oestrous cycle of the camel. The lack of precise and detailed information about the cycle has contributed to inefficient breeding and to failures in conceptions following the intensive mating procedures.

Studies conducted at the University of Khartoum provided information on the oestrous cycle and indicated the means of achieving successful breeding.

Thirty-five complete oestrous cycles were studied in five nonpregnant camels over a period of 15 months. The 28 day oestrous cycle did not have a luteal phase: the various activities were strictly follicular. Follicles matured in six days, maintained their size for 13 days and regressed over eight days. Ovulation was non-spontaneous and required the stimulus of coitus. Manual stimulation of the cervix for 15 minutes did not induce ovulation.

Clinical pregnancy diagnosis in the camel

The early diagnosis of pregnancy in farm animals is indispensable to the efficient and economical running of any livestock enterprise. The clinical features of consecutive stages of gestation for farm animals are well documented, the camel being the exception.

The clinical features of pregnancy for each month of gestation were studied in six pregnant camels which were subjected to rectal and vaginal examinations at weekly intervals over a period of 13 months.
Biological pregnancy test in the camel

This was investigated using serum from pregnant and non-pregnant camels and infant female mice. The results indicated that the test is useful in the camel between foetal crown-rump length 11 cm and 58 cm.

Studies on pregnancy and the foetus

(a) A unique membrane is described which is attached to the foetus of the camel. This membrane is produced by the deep layers of the epidermis of the skin. It starts as unkeratinized superficial layers of squamous epithelial cells which later undergo keratinization and separation from the deep layers of the epidermis except at the lips, nares, vulva, prepuce, anus, umbilicus, teat orifices and hoofs. Because of this arrangement all the foetal orifices open outside the membrane into the amniotic fluid and the rest of the body is enclosed in this membrane.

(b) In 482 pregnant uteri, each containing one foetus only, it was found that 477 foeti were in the left horn (98.96 percent) and four foeti were in the right horn (0.829 percent).

(c) In 412 cases of left horn pregnancy, 205 corpusa lutea were found in the right ovary and 207 corpusa lutea in the left ovary.

(d) In 497 pregnant uteri the incidence of twinning was only 0.4 percent.

(e) In 422 foetuses 56.16 percent were males and 43.84 percent females.

(f) The total quantity of foetal fluid in the camel is small, averaging nine litres at term. The allantoic fluid represents 80-90 percent of this throughout the gestation period. The amnionic fluid never exceeds a
volume of one litre: it remains watery throughout the
gestation period. The specific gravity of the allantoic
fluid increases progressively throughout gestation while
the specific gravity of the amniotic fluid drops during
the last third of gestation.

(g) There is a striking similarity to the bovine foetus
in development and growth curve.

(h) It was found that up to foetal crown-rump length
(CRL) of 50 cm the incidence of anterior and posterior
presentation are the same. After this there was a shift
to anterior presentation with a ratio of 2:1. At CRL
of 61-70 cm the ratio was 14:1. After the first third
of the gestation period the majority of the foetuses
were found lying on the right side with the head slightly
flexed and the limbs flexed under the body.

(i) The graafian follicle has no predilection site for
development and can be enucleated from the ovary with
digital pressure without rupturing. The follicle is
more vascular than in other large domestic animals.

BIBLIOGRAPHY

Musa, B.E. and Abu Sineina, M.E. 1976. Some observa-
tions on reproduction in the female camel (Camelus dromedarius) Acta
Veterinaria (Beograd) 26, 63-69.

Musa, B.E. and Abu Sineina, M.E. 1976. Development of
the conceptus in the camel (Camelus dromedarius) Acta Veterinaria
(Beograd), 26, 17-24.

Musa, B.E. and Abu Sineina, M.E. 1976. Studies on the
allantoic and amniotic fluids of the camel (Camelus dromedarius)
Acta Veterinaria (Beograd) 26, 107-114.

Musa, B.E. and Abu Sineina, M.E. 1978. Clinical preg-
nancy diagnosis in the camel. Vete-

inary Record 102(1), 7-13.

Musa, B.E. 1977 A new epidermal membrane associ-
ated with the foetus of the camel
C. Anat. Histol. Embryol. 6,355-358


Musa, B.E. 1979 Studies on the ovary of the camel (Camelus dromedarius) Sudan Vet. J (in press)

REPRODUCTIVE PATTERN OF THE BACTRIAN CAMEL

B.X. Chen and Z.X. Yuen

Summary

The female camel is an induced ovulator; ovulation occurs 30-48 hrs after copulation. However, the ovulation mechanism is not the same as that of the rabbit since mechanical stimulation of the cervix does not trigger ovulation. In most cases volume of the ejaculate of the male is 4.3 (3-7) ml. The concentration of spermatozoa is 615 (220-1550) mill./ml. The duration of gestation, counted from the day of ovulation, is 402.2 ± 11.53 days. In almost all cases the foetus is located in the left horn of the uterus. The anatomy of the genital organs, changes in the uterus and ovaries during pregnancy, characteristics of the foetal membranes, the parturition processes and the postpartum period are described.

Introduction

In China, the main species of Genus Camelus is the two-humped camel (Camelus bactrianus L.); the one-humped camel (Camelus dromedarius L.) exists only in very small numbers. As wool producing animals and 'ships of the desert', camels are of great value to the people who inhabit the arid regions near the deserts. Improvement of the stocks was initiated in Haixi Camel Farm in the early 1960s, but at that time knowledge about the reproduction of this species was scanty. Asdell (1946), Barmincev (1951), Lakoza (1953), Terentjev (1951) and Stugientsov (1961) were consulted but in some respects their findings were not consistent with what was observed in practice concerning, for example, the duration of oestrus and the palpation of the left ovary by rectal examination. There was no information on a reliable method of pregnancy diagnosis. It was
evident that a thorough knowledge of the reproductive phenomena would be very helpful in camel breeding. Hence, a research programme was initiated in Haixi Camel Farm in December 1963.

Anatomy of the genital organs.

Materials and methods

Female genital organs from eight adults and seven newborns, male genital organs from two adults, two castrates and six newborns were dissected. Organs of one animal of each group were sectioned for microscopic studies.

Results

The distinctive features of the female genital organs are summarized.

Ovaries

The ovary is located on the lateral side of the anterior end of the uterine horn. in the vicinity of the anterior brim of the pubis. It has a stalk 1.5-2.0 cm long, which is attached to the mesovarium. It is flat and somewhat elliptical in shape. There are many follicles, 2-3 mm in diameter, on the surface. In the absence of follicles and corpus luteum, the length, width, thickness of the left ovary is 3.2-3.5 cm, 2.1-2.5 cm, and 0.8-1.4 cm respectively; that of the right ovary is 2.8-3.5 cm, 2.2-3.0 cm, 0.6-1.2 cm.

Uterus

The uterus is bicornuate. A septum about 6 cm in length separates the posterior parts of the two cornua. The body is short, only 2.5-3.5 cm in length.

The left horn is the longer being 8-12 cm in length;
the right horn is 6-8 cm, the difference being 1-4 cm in individuals. In the newborn, the left horn is also 0.4-1.5 cm longer than the right one. At the base of the horn, it is 3.5-4.0 cm in width and the left one is generally wider than the right. The length from the fundus to the anterior end of the cervix is 8.5-9.5 cm, the width of the middle part is 4.5-5.5 cm. A dorsal groove is not present.

The whole uterus is T-shaped when relaxed. When contracted, the cornua are curved downward and backward, but not as much as that of the cow, and sometimes only one cornu is contracted (Figure 1).

The mucosa is smooth or has chequered folds, but no caruncles.

The cervix is 5-6.5 cm in length, 4 cm in diameter and is pliable. It cannot be palpated rectally. There are 3-4 (2-5) ring folds on the mucosa, some unite with each other dorsally. The vaginal part of the cervix is 1.0-1.5 cm in length, about 2.5 cm in diameter and there are many radiate folds. The os uteri is closed, but not tightly when not gravid.

Vagina and Vulva

The vagina is 25-30 cm long. The lower part of the fornix is rather indistinct. There are several large ring folds around the vaginal part of the cervix, and radiate folds which lead from the fornix longitudinally backwards and terminate before the hymen with several drumstick-like pendants.

The vulva is 6-7 cm in length. The vulvar cleft is a short slit only 5.5 (4.5-6.5) cm high. Intromission of the hand is always resisted. The clitoris is very small.
Broad Ligaments

The left ligament is significantly larger than the right one. Measured from its attachment at the side wall of the pelvic inlet to the apex of the left cornu, it is about 33 cm long, whereas the right side is only about 21 cm. The same is true of the newborn, about 7.5 cm for the left side, 5.4 cm for the right side. Since the left ligament is large, contraction of the left cornu makes it form a fold, and the ovary is pulled beneath this fold. The pedicle of the ovary is long. Thus the position of the left ovary is not consistent and usually it is not as easily palpated as the right one.

The ovarian bursa is much larger than that of other animals. It is divided by a septum into a lateral and a medial chamber. The lateral one is the infundibulum.

Uterine Arteries

The arterial supply of the female genital organs of the camel is unique in that there is no middle uterine artery.

The utero-ovarian artery arises from the aorta at the middle of the 5th lumbar vertebra and before the origin of the posterior mesenteric artery. It passes into the broad ligament and forms numerous coils, surrounded by and associated closely with the pampiniform plexus of the utero-ovarian vein. Except for the anterior uterine artery, the ovarian artery and small branches to the ovarian bursa and oviduct, it differs from other animals in that it gives rise to recurrent arteries, which are usually three in number, pass along the smooth muscle strands upward in the broad ligament and ramify under the peritoneum of the lateral side of the kidney. The first recurrent artery, which is near the pampiniform plexus and more constant than the other two, crosses the posterior ventral surface of the kidney medially and anastomoses with a very small artery which arises from the ventral surface of the aorta at the anterior end of 5th lumbar vertebra.
The posterior uterine artery is the main artery of the genital tract. It is the main branch of the urogenital artery which is the continuation of the internal iliac artery and one branch of bifurcation located about 8 cm behind the promontory and 5-7 cm from median line of sacrum. The urogenital artery curves downward to the vagina and is continued by the posterior uterine artery which pursues a flexuous course along the lateral side of the anterior part of the vagina, cervix, and the lesser curvature of the cornu, giving branches to them and eventually anastomosing with the anterior uterine artery (Figure 2).

Oestrus of the female

Materials and methods

Two herds of two and three years old camels were observed for oestrus. In a herd of 69 females, 7-20 years of age, breeding season and oestrous phenomena were investigated. Twenty-three of them, with the perineal region aproned to protect against copulation, were tested and examined rectally after testing every morning. In 13 of them, vaginal examination was also applied once when in heat.

In studying the oestrus cycle and ovulation mechanism, females with developing follicles were treated as follows, 20 animals acting as controls:

1. Mounted (with no penile intromission): 20 animals. The mount duration exceeded three minutes. The animals were mounted once, or once every day for 2-3 days.

2. Copulated: 26 animals (one with two follicles), and four animals in which the follicles had started to regress.

3. The cervix stimulated: twelve animals. Stimulation
was applied once by an insemination tube or a long probe for five minutes. Three of them were stimulated for two days and one camel was mounted before stimulation.

4. Inseminated: eleven animals. Uterine horn insemination (3-8 ml. fresh semen deposited in the cornu and the vaginal portion of the cervix massaged for three minutes) for three animals. Cervix insemination (3-8 ml) fresh semen deposited in the anterior portion of cervix and massage) for six animals. Vaginal insemination (4 ml. fresh semen deposited in the anterior portion of vagina) for two animals including one with two follicles. Prior to uterine and cervical inseminations, five animals were mounted.

Results

Age of sexual activity

1. Puberty

Sexual activity of the female camel commences at three years of age. If males are present in the female herd, calving occurs when they are four years old.

2. Breeding age

Depending upon the bodily development, female camels are usually bred when they are 4-5 years old. They can breed for 15 years and not uncommonly will give birth when over 20 years of age.

Breeding season

From the results of testing and rectal examination of follicles, the breeding season began in the first half of January in 87 percent of cases. The initiation of the breeding season appears to be related to increasing
daylight length. Only a few camels came into oestrus at an earlier date (mid-December) or later (last ten days of January).

At the beginning of the breeding season, three out of 23 animals (13 percent) refused the male when tested, although they had follicles with a diameter of over 1 cm. When they were force-mated, they ovulated and two conceived. This indicates that silent heats may occur as in the sheep.

When entering the breeding season, most of the females were mated and conceived. The male camels ceased to be in season after mid-April, and it was no longer possible to determine whether or not the non-pregnant females were still in heat. Therefore it was considered that the breeding season terminates in mid-April as for the male.

The Follicle Cycle

1. Morphology of the follicle

The mature follicle was found to be round in shape, but some were elliptical. The main part protruded over the surface of ovary and sometimes the connection between the follicle and the ovary was so small that it could be moved to and fro.

The maximum size was 1.7 (1.1-2.4) cm in diameter (long axis).

2. Development of the follicle and oestrus

Just before the onset of the breeding season, rectal examination revealed in some animals 1 or 2 follicles larger than 0.5 cm in diameter. However, they did not grow larger than 1.0 cm in diameter, regressed quickly and there was no oestrus. This is thought to be a transitional period. Once a normal follicle was detected
growing, it took 14-24 (10-29) days, averaged 19 days in 20 cases, from the initiation of development (approximately 0.5 cm in diameter) to beginning of regression.

Where coitus did not occur, the follicles developed and regressed successively. In 60 percent of cases, a new follicle started to develop within two days of the initial degeneration of the old follicle, and in 90 percent of cases within five days.

In nine of 63 animals (14 percent), two follicles developed simultaneously reaching a diameter of 1.0-1.4 cm, both were either situated in the left ovary or there was one on each side. They could ovulate together when mated, but one of them might regress earlier than the other one (Figure 3).

In a few animals, some follicles started to regress abruptly at the 6-8th day when they reached a diameter of 1.0-1.5 cm, only to be replaced by a new follicle.

When the follicle began to grow rapidly, the female camel was in oestrus; she lay down when the male approached and accepted copulation. However, the external indications of oestrus were inconspicuous, and testing was found to be the only reliable method of detecting oestrus.

Since the female camel is an induced ovulator, the follicles developed successively when mating did not take place and the heat period lasted for a long time, in some cases for over 70 days. Only a few were off heat for a few days between the development of the two follicles.

When in oestrus, the genital tract had no apparent changes. The cervix became softer, but only admitted one finger. The vagina felt somewhat slippery, but no mucus was expelled from the vulva.
3. Ovulation and its mechanism

For twenty-six developing follicles reaching a diameter of 1 cm or more, and with the duration of copulation exceeding 2.5 minutes, all ovulated 30-48 hours after mating. In two animals, with two simultaneously developing follicles, mating caused ovulation of both follicles. In another four cases in which the follicles had started to degenerate copulation did not induce ovulation.

The ovulation process could be detected clearly. At first, when only a little fluid was expelled, the follicle felt soft and could be made oblate. When more fluid was drained, the follicle felt like a small empty rubber ball. Eventually all the fluid was drained, the follicular wall collapsed and could no more be palpated.

Mounting did not trigger ovulation, nor did mechanical stimulation of the cervix. Therefore, the mechanism is considered to differ from that of the rabbit. In nine animals, uterus and cervix inseminations did not induce ovulation: one exception is considered below. In two animals, vaginal insemination caused ovulation as in natural service.

4. Corpus luteum spurium

Rectal examination revealed that CL commenced to form 1-2 days after mating. When double ovulations occurred, they both formed corpora lutea, but one day later. The mature CL was similar to a mature follicle in shape, size, hardness and connection with the ovary. The CL was yellowish in colour.

From ovulation to maximal development of CL, at 1.50 (1.10-2.30) cm in diameter, required 7.30 (5-10) days. Maximal size was retained for three days, then regression occurred (10.55 (10-12) days after ovulation.
5.1±2.0 (2-8) days after ovulation, oestrus ceased and the female camel refused the male. At first, it stood up when the male approached; later, it squatted, the tail curled up and urination took place.

If not fertilized, a new follicle started to develop 4-6 (2-10) days after ovulation, the average being 5.30±1.85 days. When the CL started to shrink, the new follicle began to grow rapidly; at about the same time the female camel accepted mounting again (Figure 4).

5. Activity of the ovaries

Of 63 normal follicles, 33 (52.3 percent) developed in the left ovary and 30 (47.6 percent) in the right ovary.

Discussion

It was generally thought that the breeding season of the female camel terminated in April as for the male. However, rectal examinations carried out from May to November revealed developing follicles 1.0-1.5 cm in diameter in a few non-pregnant, non-suckling camels. This result is consistent with the opinion of Shalash and Navito (1964) that female camels have a strong tendency to seasonal breeding, but follicle development does occur in a few non-suckling camels in the non-breeding season. Since no rutting male camel was available, it was not possible to test their sexual behaviour and to observe whether or not the follicles would ovulate.

Shalash and Navito (1964) suggested that some type of stimulus, such as copulation or mechanical or electrical stimulation of the cervix would be necessary for ovulation of dromedary camel. Ovulation in the alpaca is not spontaneous and can be induced by mating or HCG injection. Fernandez-Baca et al. (1970) found the alpaca was an induced ovulator but ovulation might occasionally be spontaneous. They concluded that mounting accompanied
by penile intromission were necessary for LH release and ovulation. Recently, Musa and Abu Sineina (1978) have shown that ovulation in the dromedary is not spontaneous, the stimulation of mating being necessary. Our findings agree with those of other investigators in that ovulation of the bactrian camel is induced. However, mounting and stimulation of cervix, separately or together, are not effective. Vaginal insemination did elicit ovulation; nevertheless, the experimental cases were too few, and more work is needed before a firm conclusion can be reached. Uterine and cervical inseminations did not cause ovulation save in one case in which clandestine mating must have occurred.

In Haixi Camel Farm camels in oestrus were usually mated twice with an interval of one day. Infertility was uncommon, the fertility rate being as high as 98-100 percent in some herds.

Rut of the male and copulation

Materials and methods

In two breeding seasons, the sexual behaviour of 21 adult males of different ages were recorded. Three herds of 2,3, and 4 year old male camels were observed.

One hundred and thirty matings were seen and 103 of them recorded. Twenty-eight semen samples were collected, using a bovine artificial vagina (Plate 1) and studied microscopically. Ejaculates were collected from five animals with a boar artificial vagina (without collection tube).
Results

Age of sexual activity

1. Puberty

Puberty of the male was observed to commence at around four years of age, although some exhibited sexual activities when they were three years old.

2. Breeding age

In Haixi Camel Farm, male camels were allowed to mate when they were 5-6 years old. In general, breeding ability declines after 15 years of age, but many sturdy males are still good stud stock at over 20 years of age.

Breeding season

The male bactrian camels had a clearcut rutting season which was from about 10th December to mid-April. Some showed sexual displays at the end of November. Robust and vigorous males were in social dominance from the commencement of the season and were called winter rutters. Individual breeding activity lasted for 50-100 days. The rut performances of younger and weaker male camels was inhibited until the sexual activity of the winter rutters began to decrease; they are referred to as spring rutters.

Rutting performances

The male bactrian camel is ordinarily a tame and calm animal. However, once the breeding season commences, its behavior undergoes distinct changes. When the animal becomes sexually aroused, the lips are smeared with saliva foam and a 'to-to' sound is uttered. It grinds the teeth continuously. Frequently it rubs the poll on the forehump and the neck and head on the ground. It often adopts a squatting posture with the
croup lowered, the hindlegs wide apart, the tail beating up and down and urination taking place. Males of about the same physical constitution and rutting intensity follow each other all day, resisting with shoulder or body and trying to bite the legs of the opponent. The subordinate younger and weaker males dare not enter the herd and their sexual performances are restricted.

The poll glands secrete and their activity seems to be influenced by intensity of rutting. The appetite decreases sharply, the abdomen becomes smaller and by the time rut is over, the male camel has reached a stage of emaciation.

Copulation

1. The female is recumbent as when resting; the male straddles her from behind. The mating posture is the same as for the alpaca.

From 103 copulations recorded, the duration of coitus was 2-4 (1-6) minutes in 86 percent of cases, 7-10 minutes or longer in others.

During intromission, the hook-formed apex of the penis rotated and ejaculation occurred several times. Semen was ejaculated at the anterior end of the vagina.

2. Semen can always be collected easily with a bovine artificial vagina. It is whitish in colour, creamy, odorless, and with a little gelatinous material. It is not as dense as that of the stallion. The ejaculate averaged 7.72 (2-28) ml from 28 samples. However, in 20 cases (71 percent) the ejaculate was 4.3 (2-7) ml; others exceeded 10 ml, the largest one observed was 28 ml. Other characteristics are shown in Table 1.
Gestation

Materials and methods

Rectal examinations were performed in pregnant camels monthly. 8-37 animals every month from 1 to 13 months. Vaginal examinations were performed on 4 non-pregnant camels and on 18 camels in differing gestation periods.

The genital organs of camels pregnant at 6-7 and 11 months were observed.

Results

Duration of gestation

Counted from the day of ovulation, the gestation period was 402.22±11.5 (374-419) days in 23 animals. That for 16 female foetuses was 400.87 days, for seven male foetuses 405.28 days.

Some phenomena of pregnancy

When pregnant, monthly changes of the internal genital organs are reliable indicators in pregnancy diagnosis and can easily be detected by rectal examination. The main changes, which differ from those in other animals are as follows:

The corpus luteum verum is similar to the corpus luteum spurium in shape, consistence and connection with the ovary, but it is much larger than the latter, the diameter or long axis being 2.6 (1.8-3.5) cm. A corpus luteum larger than 2.5 cm can be accepted as an indication of pregnancy.

In 57 pregnant camels the foetus was located in the left horn in 55 cases (96.49 percent), the other two cases were not verified.
From the beginning of gestation, the increase in volume occurs mainly in the left horn, the right horn resembling a process of the left one; this could be taken as a sign of gestation in early pregnancy diagnosis. In about 14 percent of cases, however, the uterus might temporarily present exceptional shapes from two to four months after which it was not possible to palpate the whole uterus.

The tonus of the uterus can change considerably; sometimes it is so soft that it cannot be palpated, at others it may contract so rigidly that wrinkles appear on the dorsal wall of the left horn.

Throughout gestation, mucus is scanty in the vaginal cavity and, since the vulva is so small that intromission of the hand causes resistance by the animal, vaginal examination is not recommended in pregnancy diagnosis.

Since a persistent corpus luteum was rare, resistance to the male could be regarded as a sign of pregnancy. Where fertilization has not occurred the female may refuse the male, but not over 12-14 days. Thus, pregnancy diagnosis may be made two weeks after mating based on the response to the male.

Parturition

Materials and methods

Changes in the vulva, croup, udder and teats, and in behaviour before parturition were checked daily in 26 animals; later, the processes of labour were surveyed and the duration of the individual stages were recorded.

Twenty foetal membranes were examined and foetal fluids measured.

Twenty-seven postparturient camels were examined
rectally every 1-3 days until involution of genital organs was completed. Three camels with developing follicles were mated.

Results

Signs of approaching parturition

Immediately before parturition, the most reliable indications of the onset of labour are uneasiness and a tendency to seek solitude by wandering from the herd. This is especially true for the primiparous animals.

Processes of parturition

1. In the first stage, the cervix relaxes gradually until the demarcation between uterus and vagina vanishes; part of the amnion and the forefeet are forced through the dilated cervix into the vagina. In two animals expulsion only began an hour after the foetal head had entered the vagina. During the first stage straining is not exhibited.

2. From the onset of the second stage, the animal lies down and tenesmus occurs. The whitish, transparent, avascular amnion appears at the vulva, and the feet of the calf can be seen. The foetal membrane that appears through the vulva first is always the amnion.

The presentation, position and posture of the foetus are similar to those of the foal. Only one posterior presentation was observed: the foetus was dead and ankylosed.

Since the head of the foetus is small, it passes through the pelvic cavity easily. In primiparous animals the head of the foetus ruptures the hymen and sometimes light bleeding ensues. The amnion almost always breaks outside the vulva.

Passage of the foetal thorax through the vagina
requires the greatest expulsive efforts. The placental circulation is impeded as a result of the powerful contraction of the uterus, and the foetus begins to inhale with the mouth wide open. The jugular vein bulges and in the cervico-mandibular triangle its diameter might reach 3-3.5 cm. After the thorax passes through the vulva, the hindquarters are expelled rapidly. The umbilical cord ruptures simultaneously in the majority of cases (25 out of 30).

The duration of the second stage counted from commencement of straining to expulsion of the foetus was 26.8±12 (8-50) minutes in 13 cases.

The height of the foetal thorax between tip of the forehump to the sternal pedestal was 35.7±1.9 (31-39) cm in 30 foetuses. This is much higher than that of the vertical diameter of the pelvic cavity (16.1 cm in average from 5 pelvises). However, since the forehump was directed upward and backward, the thorax was more or less pliable, and the pelvic axis (Fig. 5) and floor of the bony pelvis of the dam (averaging 15.5 cm in 4 cases) were short, the second stage was only slightly longer than that of the mare.

3. The third stage, from expulsion of the foetus to expulsion of the foetal membranes, averaged 49 (21-72) minutes in 15 cases, but in four other instances the period was prolonged to 98, 131, 170, and 184 minutes.

In 19 out of 22 cases (86.4 percent), the allantoic sacs were expelled integrated, the whole foetal membrane leaving the uterus without eversion.

The foetal membranes

The amnion was greatly elongated and occupied the pregnant horn from the apex to the orificium internum uteri. In the body of the uterus, the allantoic part was ventral and anterior to the end of the amnion, therefore after
rupture of the chorion and when the cervix was dilating, the amnion was always the first membrane to enter the birth canal.

The amnionic fluid at full term was 700-900 (350-1100) ml, the allantoic fluid was 6500-11 500 ml in 13 cases.

Chorion and placenta were similar to those of the foal; the placenta was of the diffuse and epithelial-chorial type.

The umbilical cord was similar to that of the calf. Measured from the umbilicus to the opening of the urachus, it was about 30 (27-32) cm in 16 cases (Figure 6).

There was a membrane totally covering the foetus, including the ear sheaths, tail sheath and leg sheaths which derived from the epidermis. Microscopic examination showed that it was composed of flattened cells attached by cellular bridges.

Parturient diseases

Apart from abortions, parturient abnormalities are uncommon in the camel. Dystocia cases encountered occasionally were due to downward deviation and lateral deviation of head, knee-flexed posture. If the two forefeet and muzzle were seen through the vulva when the camel started to strain, this indicated that the foetus was normal in presentation, position, and posture and no interference was called for. Whenever the expulsion process is prolonged, and especially when there is no sign of the muzzle or feet through the vulva, manual vaginal exploration should be initiated without delay. Where malpresentation is not excessive at the start of labour, adjustment is usually successful.

Retention of the placental membranes is very rare.
The postpartum period

1. Involution of the uterus

By two weeks after parturition the entire uterus can be palpated per rectum. At this time, the uterine wall is thick; flaccid when relaxed and rigid when contracted. Some wrinkles now appear on the dorsal surface of the horns. Twenty-five to 30 days after parturition, the uterus resumes its normal size and position, but the wall is still thick. Forty days after parturition the uterus returns to normal. Lochia ceased after about 22 days.

2. The ovary

The right ovary can be detected 3-5 days following parturition; the left ovary cannot be palpated until 5-10 days after parturition. The corpus luteum verum regresses rapidly to a diameter of 0.8-1.0 cm, then persists for about 3-4 months. This is true also of a corpus luteum following abortion.

Five to 35 days after parturition, follicles developing to a diameter of 1.0-1.4 cm were revealed in seven cases (33 percent). Three animals were mated at 12, 18, and 40 days; they had ovulated, but not settled, although some camels in other herds had given birth to normal young for two years in succession. Usually the camels delivered every two years. The low conception rate might be due to the following reasons: a) development of follicles and oestrus might be inhibited in the nursing dam, since if the calf died, the dam would be soon in oestrus and could be pregnant; b) the nutritional status of the dam was not such as to permit pregnancy. c) mating ability of the male camel had decreased toward the end of breeding season.
Table 1: Characteristics of semen

<table>
<thead>
<tr>
<th></th>
<th>Average and range</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume/ejaculate (ml)</td>
<td>7.72(2-28)</td>
<td>28</td>
</tr>
<tr>
<td>Sperm concentration (mill./ml)</td>
<td>615(220-1250)</td>
<td>14</td>
</tr>
<tr>
<td>Length of sperm (micron)</td>
<td>51.05±4.54</td>
<td>110</td>
</tr>
<tr>
<td>Length of sperm head (micron)</td>
<td>7.68±1.64</td>
<td>110</td>
</tr>
<tr>
<td>Motile sperm (%)</td>
<td>70-90</td>
<td>14</td>
</tr>
<tr>
<td>Abnormal sperm (%)</td>
<td>4.9(2.2-6.5)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Shapes of camel uterus.  
1 and 2: Both cornua contracted, dorsal and lateral view.  
3: Left cornu contracted.  
4: Both cornua relaxed.

Figure 2: Plan of arteries of female genital organs.  
Figure 3: Development of follicle.

Figure 4: Relation between development of CL and follicle. C - copulation; O - ovulation; F - follicle; CL - corpus luteum; T - response to testing; V - receptive to male; X - resistant to male; x - resistant, tail curls up and urination takes place;

Figure 5: Pelvic axis (pa) of the bactrian camel.
Figure 6: Relations between the components of the foetal membranes (cross-section of the foetal membrane sac at the distal end of the umbilical cord.

1. Outer layer of the allantois;  
2. Inner layer of the allantois;  
3. Allanto-amnion; 4. Allanto-chorion;  
8. Umbilicus; 9. Greater curvature;  
10. Lesser curvature; 11. Location of the main artery trunk.

Plate 1: Collection of the semen with a bovine artificial vagina.
BIBLIOGRAPHY

Asdell, S.A. 1946 Patterns of mammalian reproduction. 328-329, Comstock, New York


Lakoza, I.I. 1953 Verbludovostvo, Seljhozgiz, 185-202


Podberezkin, Ya 1951. Konevodstvo, 10:42-43


FACTORS INDUCING OVULATION IN THE BACTRIAN CAMEL

B.X. Chen, Z.X. Yuen and C.W. Pan

Summary

Thirty-eight female and seven male bactrian camels were used to determine the factors which would induce ovulation in the breeding season. After insemination into the genital tract, ovulation was checked by rectal examination. The results indicated that ovulation is induced by the seminal plasma. The incidence of ovulation following insemination was 83-87 percent. Spermatozoa cannot induce ovulation. The time interval from insemination to ovulation was 36 hours in 74 percent of cases; 26 percent ovulate by 48 hours which is consistent with the time interval following natural service. Observations on one male camel, showed the minimal quantity of seminal fluid necessary to initiate ovulation to be about 1 ml; 0.5 ml failed to induce it. Luteinizing hormone (LH), human chorionic gonadotropin (HCG) and luteinizing hormone releasing hormone (LHRH), injected muscularly cause ovulation in a similar manner.

Introduction

Information on the mechanism of ovulation in Camelds is scanty. Shalash and Nawito (1964) suggested that some type of stimulus such as copulation, mechanical or electrical stimulation of the cervix and other afferent stimuli would be necessary for ovulation in the dromedary camel (Camelus dromedarius). San-Martin et al. (1968) reported that ovulation in the alpaca (Lama pacos) was induced by coitus, the follicles ovulating 26 hours after coital stimulation or 24 hours after intravenous injection of HCG. Fernandez-Baca et al (1970) indicated that in alpaca, mounting accompanied by penile intromission was necessary to
provide an adequate stimulus for LH release and subsequent ovulation. Jöchle (1975) reviewed current research in coitus-induced ovulation in mammalian species. Recently Musa and Abu Sineina (1978) have shown that ovulation in the dromedary was non-spontaneous and required the stimulus of coitus; manual stimulation of the cervix did not induce ovulation. Chen and Yuen (1980) reported that mounting and stimulation of the cervix with an inseminating tube were not effective in inducing ovulation in the bactrian camel (Camelus bactrianus). Vaginal insemination did induce ovulation, but the experimental cases were too few to form a conclusion.

Inspired by the Camel Workshop held in Khartoum in 1979, the authors resumed their research work on the ovulation inducing effect of semen of the bactrian male camel in the breeding seasons of 1980 and 1981.

Materials and methods

Animals

Thirty-eight breeding camels 8-15 years in age and seven male camels 4-10 years in age were used for determination of ovulation induced by semen.

Methods

From the beginning of the breeding season the development of the follicles was checked daily by rectal examination. When the follicles grew larger than 1.2 cm in diameter, experimental materials were introduced into the genital tracts of the female camels. Hormones were also injected intramuscularly, and at 24, 36, and 48 hours following treatment ovulation was checked by rectal examination. Should ovulation have occurred within 36 (30-36) hours, the time interval was recorded as 36 and ovulation from 37 to 48 hours were recorded as 48.
1. Intravaginal administration

The following materials were deposited deeply in the vagina:

(1) Whole semen
Male camel semen was collected with a bovine artificial vagina. It was used immediately or after storage between 0°C and -20°C for differing lengths of time, subsequently being thawed and warmed to 37°C before insemination. Dosage was 1.5-7.0 ml. In four cases semen was deposited in the uterus instead of the vagina.

Stored bull, ram and boar semen were also used to test their effect on ovulation of camel, the dosage being 2-3 ml.

(2) Seminal plasma of camel
Following collection the semen was centrifuged at 2000 rmp for 7 hours. The supernatant liquid was examined microscopically and only when the sperm concentration was under 10 000/ml, was the seminal plasma used. The dosage was 3 ml.

(3) Washed camel spermatozoa of high concentration.
After centrifugation of semen, 10-15 ml saline was added to the sediment, stirred, centrifuged and the supernatant fluid discarded. This was repeated three times, the sediment being examined microscopically. The washed sperm was used with a sperm concentration of over 4-7 hundred million/ml, 3 ml per insemination, which contained 1.2-2.1 billion spermatozoa and was equivalent to a sperm count of 2-4 ml semen.

(4) Secretion of accessory sexual glands.
Male camel no. 5 was vasectomized. Collection of semen began six days after the operation and was repeated every two days until the 18th day when the sperm concentration was under 10 000/ml. Hereafter 3.5-4.0 ml of the secretion of ampulæ, prostate, urethral glands and bulbo-urethral glands was used per insemination.
In three cases this male camel was allowed to serve naturally.

(5) \( \text{PGF}_{2\alpha} 2-16 \text{ mg or HCG} \ 2000-2500 \text{ i.u.} \)

(6) Skim milk, saline or glucose solution 6 ml, as control.

The male camel was allowed to mount and 3-10 minutes following coitus, semen was flushed out of the vagina with 3000 ml of saline. The follicle was then examined rectally to determine whether ovulation had been induced without semen.

If materials did not induce ovulation, exogenous reproductive hormones were injected in order to confirm if the materials were ineffective or the follicles were unable to ovulate: LG 300 i.u.; HCG 1000-2000 i.u.; LHRH analog, 250-500 \( g \); prostaglandin (PG)F\(_{1\alpha}\) or PGF\(_{2\alpha}\), 6 mg.

Results

A. Ovulation-inducing effect of the components of camel semen

(1) Intravaginal administration of washed sperm of high concentration:

Washed sperm was used in seven cases none of which ovulated. Sperm was, therefore, assumed to be involved in the inducement of ovulation. Moreover, there was no difference in the result of ovulation whether the sperm in the semen were living or dead \( (P>0.0105) \), since in twelve animals inseminated with fresh semen eleven ovulated, and in ten animals inseminated with frozen semen in which sperm were dead, nine ovulated.
(2) Insemination of whole semen:

In 31 animals inseminated with semen of male camels Nos. 1, 2, 3, 5, 6, 7, 27 (87 percent) ovulated. None of the eleven controls ovulated (Table 1).

The minimum amount of semen required to induce ovulation was approximately 1.0 ml. All the three cases which were inseminated with no more than 1.0 ml (about 0.1-0.2 ml semen was left in the inseminating tube) ovulated while two cases which were inseminated with 0.5 ml did not.

Freezing did not cause any adverse effect on the ovulation-inducing property of semen; one sample which had been stored at low temperature for as long as 67 days, induced ovulation.

The ovulation time following insemination was similar to that following natural service. In 23 cases (74 percent) ovulation took place by the thirty-sixth hour (30-36 hr) and in eight cases (26 percent) by the 48th hour.

(3) Intravaginal administration of seminal plasma or secretion of accessory sexual glands (including three cases of natural service by male camel no. 5 after vasectomy):

In twelve cases seminal plasma or secretion of accessory sexual glands was administered intravaginally and ten ovulated. This is roughly consistent with the result of whole semen and may indicate that no synergism of seminal plasma and sperm exists in inducing ovulation.

(4) Natural service followed by flushing the vagina:

This was conducted in four cases, three did not ovulate, but one did.
B. Effect of semen of other male farm animals on ovulation in the female camel

All three cases inseminated with bull semen ovulated by the forty-eighth hour. One bull semen sample had been stored for more than 40 days. Five cases which were inseminated with ram semen and three cases which were inseminated with boar semen did not ovulate. This may suggest that the ovulation-inducing factor is not a common composition of all the farm animal semen, but it may be present in the bull semen.

C. Ovulation-inducing effect of semen of each male camel.

Seven male camels were used; the effect of semen on ovulation is summarized in Table 2.

Table 2 shows the male camel no. 4 differs from the others in ability to induce ovulation: of 13 female camels treated with the semen or seminal plasma, only three ovulated. The semen of no. 4 moreover caused cystic ovaries in three female camels. Radioimmunoassay indicated that four hours after insemination the LH level in the peripheral blood plasma of female camels which would not ovulate subsequently, was only 3.8 ng/ml in average; this is similar to that (3.5 ng/ml) of female camels in oestrus but not inseminated. In striking contrast, the LH peak of female camels which would ovulate was 6.9±1.0/ml in average (Gao, 1981). Some abnormality may exist in the reproductive function of male camel no. 4.

D. Reaction of individual female camels to semen

Among 38 female camels investigated in two breeding seasons, four were subnormal in ovulation. One case suffered from chronic cervicitis, another showed cystic ovaries after insemination with semen from fertile
male camels in two successive seasons. Both females had a history of infertility extending over many years. The other two cases did not ovulate following insemination, but they did after the injection of HCG: moreover, other female camels had reacted to semen from the same male and had ovulated. These facts indicate that ovulation is also dependent on the reaction of individual female camels to semen. Radioimmunoassay shows that LH peak of the subnormal female, four hours following insemination, was the same as that of normal females which would ovulate later; this suggests that the LH surge threshold required for ovulation in these females might have been higher.

E. Ovulation-inducing effect of reproductive hormones

Vaginal administrations of LH and HCG in two groups, each consisting of three females, were not effective; however, two animals from each group ovulated following intramuscular injection of HCG, LH or LHRH. The other two animals were not treated after vaginal administration.

Vaginal administration and intramuscular injection of PH analogue were ineffective in two groups of four and two animals respectively, but three of them ovulated following HCG injections. The other three were not injected again.

The results of the intramuscular injection of reproductive hormones are summarized in Table 3.

Table 3 shows that in the LH group all the three animals ovulated after injection, and four of the five cases injected with LHRH also ovulated. The case is rather different in the HCG treated group, for out of a total of nine animals only six ovulated. The four animals (one in the LHRH group, and three in the HCG group) which did not ovulate had been inseminated with semen of male camel no. 4. The interval between injection and ovulation in almost all cases was 36 hours.
Discussion

Ovulation in the bactrian camel is fundamentally induced by seminal plasma. This is a newly revealed phenomenon in the mechanism of mammalian ovulation; some complicating problems require to be further investigated.

It is evident that seminal plasma plays an important role in ovulation in the bactrian camel.

The inducing factor can be stored for a long time without losing biochemical activity. The particular nature and the mechanism in stimulation of LH-release following absorption remain to be clarified.

Four animals were inseminated into the uterus or deeply in the cervix in this experiment and they all ovulated, so the vagina may not be the only location where the semen is to be absorbed. The process of absorption requires further study. Four animals were allowed to be mated and the semen was flushed out of the vagina 3-10 minutes later. Three of them did not ovulate, the assumption being that ovulation could not occur without semen. However, one animal did ovulate, and it might be that in this case, flushing was too late and the semen had been absorbed into the uterus.

Since the seminal plasma was able to induce ovulation, two old male camels were slaughtered after the rut season had started (early in December), the prostates, urethral glands, bulbo-urethral glands, epididymis and testicles were collected and tissue emulsions prepared. A mixture of 2 ml of each of these emulsions was introduced into the vagina of an oestrous female, in order to ascertain if the ovulation-inducing factor might be present in certain organs. Ovulation did not occur, which might suggest that the factor is likely to be produced during the process of secretion. However, much more investigation is required in order to establish the nature of the factor. It is interesting to note that following the introduction of the emulsions, and
similarly with the PG preparations and the serum of male camel, an inhibiting effect had been observed, in that when the same female camel was inseminated subsequently with the semen of fertile male camels which could induce ovulation, ovulation would be often inhibited. Should LH or HCG be injected again, however, ovulation did occur. The semen of male camel no. 4 had a similar inexplicable inhibiting effect.

In this experiment, ovulation after insemination occurred in only 83-87 percent of cases, while our previous work in 1963-1965 showed that ovulation took place in all of the 26 female camels which were mated naturally. Coital behaviour might therefore contribute to a lesser extent to the mechanism of ovulation.

Lastly, in the four cases which did not ovulate following insemination with the semen of male camel no. 4, HCG or LHRH were injected and ovulation occurred. This indicates that the follicles were able to ovulate, but the ovulation-inducing capacity of this male camel was poor. At four years of age, it was the youngest in the male camel group. Age might play a role in ovulation-inducing ability but evidence is required before such a conclusion can be reached.

Conclusions

There were differences of opinion among investigators and practitioners concerning the pattern and nature of the oestrous cycle of the camel. Earlier information on the oestrus of the Camelidae indicated that they were induced ovulators. This study confirms our previous finding that the bactrian camel is also an induced ovulator; however, the mechanism is different from that of the rabbit. Mounting and stimulation of cervix are not effective, nor is the sperm. The inducing factor exists in the seminal plasma of the semen (the mixed secretion of the ampullae, prostates, urethral glands and bulbo-urethral glands). Following insemina-
tion, either into the vagina or into the uterus, ovulation will occur in 83 to 87 percent of the female camels. Bull semen triggered ovulation in three cases. Ovulation can also be induced by LH, HCG and LHRH. The time interval from insemination to ovulation is within 36 hours (30-36 hrs) in 74 percent of cases; 26 percent ovulated by 48 hours, which is consistent with the time interval observed after natural service. Using male camel no. 2 as an example, the smallest amount of semen necessary to induce ovulation is about 1 ml; 0.5 ml is insufficient.

Not all semen samples will induce ovulation, nor will all the females ovulate invariably after insemination. Ovulation might depend on the quality of the semen and the physiological condition of the females. Four hours following insemination with the semen of a subnormal male camel, the peripheral LH peak in a female camel which will not ovulate subsequently is similar to that of untreated oestrous females and much lower than that of females which would ovulate later. This provides a reasonable explanation for the low ovulation-inducing rate of this male camel. However, in a few females inseminated with semen of normal males the LH peak is the same as that of normal female camels, yet their ovulation response to semen is poor. Radioimmunoassay has allowed a far greater understanding of the endocrine events underlying ovulation, but much more work has to be done before this question and the problems presented in the discussion can be solved.
Table 1: Ovulation-inducing effect of different materials administered intravaginally.

<table>
<thead>
<tr>
<th></th>
<th>Dosage</th>
<th>No. Ovulations</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washed camel sperm</td>
<td>1.2-2.1 billion</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Camel whole semen</td>
<td>1.7 ml</td>
<td>31</td>
<td>27(87%)</td>
</tr>
<tr>
<td>Seminal plasma or secretion of accessory sex glands</td>
<td>3.5-4 ml</td>
<td>12</td>
<td>10(83%)</td>
</tr>
<tr>
<td>Controls</td>
<td>6 ml</td>
<td>11</td>
<td>11</td>
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</table>

Table 2: Ovulation-inducing effect of each male camel

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<th>Male camel</th>
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<th>Condition</th>
<th>Work</th>
<th>Ejaculate (ml)</th>
<th>Viscosity</th>
<th>Motility of sperm</th>
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<td>1</td>
<td>6</td>
<td>good</td>
<td>light</td>
<td>4.10</td>
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<td>3</td>
<td>9</td>
<td>poor</td>
<td>medium</td>
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<td>nil</td>
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<tr>
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<td>poor</td>
<td>nil</td>
<td>4.02</td>
<td>thick</td>
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<table>
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<th>Male camel</th>
<th>Inseminations ovulations</th>
<th>No response</th>
<th>Matings ovulations</th>
<th>No response</th>
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Table 3: Ovulation-inducing effect of reproductive hormones.

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<th>Ovulations</th>
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<td>300 i.u.</td>
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<td>LHRH</td>
<td>250 g</td>
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<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500 g</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<td>HCG</td>
<td>1 500 i.u.</td>
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<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 000 i.u.</td>
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<td>1</td>
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<tr>
<td></td>
<td>3 500 i.u.</td>
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REFERENCES


PREGNANCY DIAGNOSIS BY RECTAL EXAMINATION IN THE BACTRIAN CAMEL

B.X. Chen and Z.X. Yuen

Summary

Although pregnancy diagnosis by rectal examination has been thoroughly studied in the cow and mare, the camel has received relatively little attention. As part of the research programme on camel reproduction conducted from 1963 to 1965, a study was undertaken on early pregnancy diagnosis in connection with camel breeding. Semimonthly and monthly changes in the internal genital organs are described.

At the sixth week of pregnancy, the left horn and body of the uterus appear larger than the right horn. Furthermore, the corpus luteum verum is usually larger than the corpus luteum spurium. Pregnancy diagnosis by rectal examination is therefore simplified from the sixth week onwards.

Materials and methods

Pregnant camels were examined per rectum every two weeks from the first to the third month. Thereafter they were examined monthly.

Results

One month (37 animals)

The wall of the left gravid horn was soft and thinner than that of the right horn. Following stimulation by manipulation, both cornua or the left horn alone would contract and curl temporarily into the shape of a rams horn. Simultaneously the left horn and body assumed a tubular shape and had a tonic feel, but not as hard
as a contracting non-gravid horn. Since the changes were not apparently different from a non-pregnant uterus, they were not reliable indications of pregnancy.

A large corpus luteum was located in one ovary; when its diameter exceeded 2.5 cm, this might indicate that the camel was pregnant. The average diameter of the corpus luteum verum was 2.6 (1.8-3.5) cm, whereas the corpus luteum spurium measured only 1.5 (1.1-2.3) cm.

1.5 month (33 animals)

The left horn was usually 10-15 cm in length and 5-8 cm in width at the base, whereas in the non-gravid state the length was 8-12 cm, and the width 3.5-4 cm. The right horn remained unchanged. The width at the middle of the body (actually from the fundus of the uterus to anterior end of the cervix) was 5-8 cm; when not gravid the width was 4.5-5.5 cm. Since both the left horn and the body were enlarged, they felt like a tube directed forward and to the left, while the right cornu felt like a smaller process of them. Because of this peculiarity, it was simple to make a positive pregnancy diagnosis at this time.

The wall of the uterus and especially the left horn was usually relaxed, therefore the left horn curved only slightly and the right horn straightened out. The wall might become slack temporarily, but the tonus would quickly resume and it became palpable again.

The uterus might contract occasionally, the wall became tense and the left horn curved downward and backward; sometimes both horns contracted and the bifurcation was not palpable. In about one-fifth of the cases a few wrinkles appeared on the dorsal wall of the body. Contraction lasted only a short time.

The primary corpus luteum grew larger than at one month in some cases. In addition, in 92 percent of cases
there appeared another one or two smaller corpora lutea (1.0-1.5 cm in diameter).

Two months (29 camels)

The left horn was 15-20 cm long and 8-10 (7-12) cm wide at the base and the width of the body was similar. The impression was of a tube, distinctly longer and thicker than the right horn.

The uterus was similar to the gravid uterus at six weeks in shape and tonus, but when contracted the body felt much longer than at six weeks. Foetal fluid could be perceived.

From the end of the second month to the fourth month, parts of the uterus could present exceptional shapes.

The ovaries shifted forward and were located just in front of the pubic brim.

2.5 months (25 animals)

The left horn became so large that the apex was often out of reach; the body had obviously enlarged to a width of 10-12 (8-15) cm at the middle. The right horn was distinctly smaller being only 10 (8-12) cm long and 5-8 (4-10) cm wide.

The uterus was usually relaxed as before, the left horn curved only slightly or pointed forward and to the left. A temporary slackness of the wall was still occasionly encountered.

When contracted, the wall thickened, felt firm and wrinkles appeared on the body in 11 cases (44 percent). If the left horn curved sharply, then the bifurcation of the horns could not be palpated.

Foetal fluid and the exceptional shapes of the uterus were similar to those of the two months pregnancy.
The left ovary was shifted further anteriorly from the brim of pubis and since its position was inconstant, it could not be located in half of the cases. The right one could usually still be detected. The corpus luteum was similar to that of the six weeks pregnancy.

Three months (22 animals)

The left horn and body enlarged steadily. Depending upon the intensity of tonus, the base of the left horn was 10-15 cm in width, and 10-16 cm wide at the middle of the body. They directed forward and to the left, the apex was generally out of reach but the bifurcation could usually be felt.

When contracted, wrinkles appeared on the body in 15 cases (68 percent).

Fluctuation of foetal fluid could be easily detected. Exceptional shapes of uterus were similar to those of the 2.5 months pregnancy.

In about 65 percent of cases the left ovary could not be located: the right one could usually be found without difficulty.

The left urogenital artery was slightly larger in size than the right one in half of the cases.

NOTE: The contracted gravid uterus of 2-3 months is similar to a distended bladder in size and shape. In distinguishing between them the characteristic right horn of the uterus can be detected with careful palpation; furthermore, since the right broad ligament is much narrower then the left, the uterus must shift to the dorso-dextral side of the bladder when distended.

Four months (19 animals)

The size of the left horn could not be measured due to enlargement, especially when the wall was relaxed. In
half of the cases, the bifurcation could not be reached. The body was 10-18 cm wide at its middle, the difference being caused by intensity of contraction.

The wall of the uterus was soft or tense depending upon the state of relaxation or contraction. When relaxed, the foetal fluid could be perceived clearly. When contracted, wrinkles could be palpated on the body in nine cases (47 percent). The exceptional shapes of the uterus were as before.

The left ovary could be located only occasionally, since it had shifted far forward and downward. The right ovary could still be found in front of the pubic brim but not as easily as before.

The left urogenital artery was larger than the right in 60 percent of the cases.

Five months (24 animals)

Since the whole uterus hung deeply in the abdominal cavity, the bifurcation and the right horn could not be reached in 18 instances (75 percent). The body did not enlarge further and the tenseness and wrinkles were basically similar to the stage at four months. However, fluctuation was not as obvious as at four months, and the uterus felt like an empty bag hanging from the pubic brim downward and to the left. Temporarily the uterus might be too soft to be palpated; when contracted, however, the body was tube-like and the foetus could occasionally be detected in front and to the left side of the pubis. The foetus was usually below the level of the pubis.

The left ovary could no longer be palpated and the right ovary could only be located through widespread palpation.

The left urogenital artery was larger than the right in about 75 percent of cases, and in a few animals
fremitus could be recognized. The right urogenital artery was also usually larger in size than in the non-gravid state.

Six months (19 animals)

In all cases the bifurcation and right horn were out of reach. The body of the uterus was slightly larger than that at four months, being 12-16 (12-20) cm in width. It was usually flabby, and directed forward, downward and to the left. When contracted, it was tube-like and the wall had a tonic feel; wrinkles occurred in eight animals (42 percent).

In seven cases (37 percent) the foetus was palpated temporarily in front and to the left of the pelvic inlet and below the level of the pubic brim. Only in one animal was the foetal fluid perceived clearly. The ovaries could not be located.

In 17 cases (89 percent) the urogenital artery was larger on the left side than the right and fremitus was recognizable in nine animals (47 percent). At this time, the fremitus was much like that of the cow in that it occurred intermittently, and was sensed more clearly when the palpated site was closer to the uterus and the artery was pressed lightly. In 16 cases (84 percent) the right urogenital artery was perceptibly larger than that of non-gravid animals.

Seven months (18 animals)

The body of the uterus was similar to that of pregnant camels at six months but wrinkles occurred in only 22 percent of cases.

In seven animals (39 percent) foetus was palpated temporarily under the left kidney and in front of the pubis. Movement of the foetus was more active than that of the calf, but not as much as the foal.
The left urogenital artery was distinctly large, the diameter of its origin was about 0.8-1.0 cm in general; a few were slightly larger. Fremitus was evident in 13 animals (72 percent), it was however still intermittent in some cases. The diameter of the right artery had reached 0.6-0.8 cm, three of them presented feeble fremitus.

Eight months (15 animals)

The shape, tenseness and wrinkles on the wall of the body were similar to those at seven months gestation.

In eleven cases (73 percent) the foetus was palpated right under the left kidney. Usually it moved immediately forward and downward through stimulation.

The diameter of the urogenital artery at its origin was 1.0-1.2 cm. In 13 cases (86 percent) the fremitus was pronounced and sometimes it could be felt at a touch; in some animals, however, it could be perceived only by pressing the artery. The diameter of the right artery was 0.8-1.1 cm, in six animals (40 percent) fremitus was present.

Nine months (14 animals)

The shape and tonus of the body of the uterus were the same as before, but wrinkles were discovered only in two camels (14 percent).

Movement of the foetus was active.

The diameter at the origin of the left urogenital artery was 1.1-1.4 cm; fremitus could be recognized clearly in all cases. The diameter of the right artery was 1.0-1.2 cm, in seven cases (50 percent) fremitus was felt intermittently.
Ten months (3 animals)

The uterus was nearly the same as before. Fremitus occurred in the right urogenital artery in all three animals.

Eleven months (7 animals)

Wrinkles still occurred on the body of uterus in two animals. The foetus was palpable in all cases, parts of some foetuses had entered the pelvic cavity and could be palpated when the hand was introduced into the rectum. The position of the foetus was inconstant and it could move forward and backward.

The diameter of the left urogenital artery was 1.1-1.4 cm, fremitus was very distinct to the touch; in one camel, however, the artery had to be pinched tightly in order to sense the thrill. The right artery was slightly smaller in size; fremitus was recognized in four animals.

Twelve months to preparturition (13 animals)

The foetus was palpable in all cases, but once during examination the foetus moved forward and could not be reached.

The diameter of the left urogenital artery was 1.2-1.4 cm, the right side was smaller; in a few cases, however, both arteries were nearly the same. Fremitus at both sides was generally distinct and could be recognized when the hand was approaching them. However, in one case fremitus of both sides was not obvious, and in another, no fremitus was sensed on the right side.

BIBLIOGRAPHY

A NOTE ON CASTRATION OF THE DROMEDARY

H.R. Cran

Although not practised in all countries in which camels are found, castration has certain advantages such as obviating the effects of musth, involving as it does extra trouble in handling, fighting and injuries. Castrated males and females may be worked together. Although geldings are not as strong as entires and are unable to carry such heavy loads, they are more tractable. In addition, geldings being lighter in build may be more suitable as riding camels.

A cheap, effective and simple method of anaesthesia is desirable bearing in mind the conditions and location where camel handling operations are likely to take place. Suitable drugs include the following.

1. chloroform;
2. etorphine with acepromazine (Immobilon) and the antagonist diprenorphine (Revivon LA), 0.5 ml per cwt;
3. chloral hydrate and sodium citrate 1% solution i/v;
4. xylazine (Rompun) 2% 0.25 mg per kg;
5. chloral hydrate/magnesium sulphate.

Taking into consideration the cost of the drugs, possible adverse side-effects and the skill of available personnel, Rompun (xylazine), used in conjunction with a local anaesthetic, is the drug of choice. It is well tolerated, highly effective and easily administered.

Although the use of the bloodless pressure emasculator has been advocated in the past, the anatomy of the camel does not render it a suitable subject. The spermatic cords are short, almost horizontal and difficult to grasp. Failures are common.

Camels intended for baggage work should not be
castrated under the age of four years. They should be starved for 24 hours before castration.

When there are a number of camels to be castrated, say up to twelve, it is convenient to instruct the camel handlers to couch their camels, hobble one foreleg and then administer Rompun 2% at a dosage rate of 0.25 mg per kilogram by intramuscular injection in the gluteal muscles to all the camels to be castrated. After about twenty minutes the operation can begin on the most sedated animals; by the time one or two operations have been successfully completed, the remaining patients should be adequately sedated.

The animal is rolled on to its right flank and the fore and hind legs secured with rope, with the hind legs well drawn up. The lower eye is protected with a piece of sacking. Local anaesthetic procaine hydrochloride with approximately 20 ml adrenaline is injected into each testicle and spermatic cord. The scrotum is incised near to the median raphé, the testicle is then withdrawn through the incision and the spermatic cord is crushed and cut with a horse emasculator. The cord should be ligated with no. 3 or 4 chromic catgut. Post-operative bleeding or swelling will not occur. The second testicle is removed through the same incision and the wound then sprayed with an antibiotic/gentian violet aerosol spray and left open. An antibiotic and tetanus antitoxin should then be given by intramuscular injection. Recommended drugs are (a) ampicillin trihydrate BP (3000 mg ampicillin) 20 ml, or (b) 20 ml penicillin/streptomycin (5000 mg dihydrostreptomycin as the sulphate and 4 mega units of penicillin G. procaine) by intramuscular injection to average weight camels. Other antibiotics such as oxytetracycline may also be used.

Finally the ropes are untied, always the hind legs first. The camel is rolled on to its brisket, and generally it will rise to its feet and move off to graze.
This routine has been satisfactory in general use, with no cases of haemorrhage or swelling, no fatalities and no apparent loss of condition.

BIBLIOGRAPHY


SECTION E

CAMEL PHYSIOLOGY AND ADAPTATION
ASPECTS OF DROMEDARY ECOLOGY AND ETHOLOGY

Hilde Gauthier-Pilters

Summary

Ecological investigations of free-ranging camels were carried out for a total of 3 years in the period 1954-1978. The main objective was to ascertain the food and water requirements of the camel. One third of this time was during the hottest season. Prior to studying the animals in the field, the behaviour of captive Old World and New World camelids was observed over a period of 2 years. Camels are the only domestic animals which can utilize the most scattered vegetation without damaging the environment. They range widely, move constantly, need little food, show seasonal food preferences, and have an exceptional tolerance to dehydration. They exploit vast desert areas, far distant from wells, which are inaccessible to other domestic animals. They graze and browse on plants which are ignored by other livestock. This study, which was carried out in close cohabitation with the nomads and their herds, showed that both live in a balanced ecosystem.

Location

The study was done in the western and northwestern Sahara, an area comprising the area of Beni-Abbès in southern Algeria, western Algeria along the Mauritanian border, northern Mauretania and middle Mauritania. These regions are arid, receiving irregular and rare rainfalls of not more than 50 mm/year or, in middle Mauritania, about 100 mm. However, mean values have little significance since rainfalls are extremely irregular from year to year and often localized; only highly mobile animals like wild ruminants or camels can benefit from them. Apart from northern Mauritania, which is under the influence of the Atlantic Ocean, and the coastal regions, maximum tempe-
ratures in summer exceed 40°C almost every day and often reach 46°C. The minimum temperatures rarely descend below 25°C.

The western Sahara has mostly flat terrain without great river beds and this facilitates large scale movements. The terrain consists of hamadas (rocky plateaus) and regs (gravelly plains), some mountain reliefs of a maximum height of 800 m, dune regions and immense flat sand areas. Vegetation is dispersed and irregular. Camels must cover great distances to find a reasonably balanced diet in the various biotopes which may be separated by large stretches of barren land. The distance between two wells might be 100 km or more. Development and settlements are few and far between and the rare roads are mostly impassable to vehicles. There is no tourism. The climatic and soil conditions allow no agriculture or intensive livestock rearing. Camel herding, however, can successfully use such areas which otherwise would be totally unproductive. Conditions are favourable for camel nomadism in which man and the animal are closely inter-dependent.

In the Beni-Abbès region, semi-nomadism has always prevailed, being encouraged by the relative frequency of oases, in which the nomads possess land and palm trees. The herds can exploit ecologically distinctive zones like the erg (dunes), hamada wadi (dry river bed with salty vegetation), and the djebel (mountains), without the efforts required of the Mauritanian camels. Many of the nomads, predisposed to an easier life, have now settled. As long ago as 1969 it was observed by the author that the extension of the oases and the increased requirement for firewood and straw was having a disastrous effect on the surrounding pastures.

The Reguibat

In Mauritania so much importance is given to camel breeding that even former nomads who have settled down
will buy camels from their savings and place them in the care of herdsmen. The prestige of a person, be he a nomad or a minister, still depends on the number of camels which he owns. However, drought has ruined many west Saharan nomads and political troubles in this part of the desert have caused the restriction of pastoral movements during the last few years.

Of the many tribes which live with the camel, the Reguibat are likely to have the greatest chance of survival. Of all the tribes, they resist most strongly the temptations of an easier life. They avoid settlements and their large camel herds call for great mobility, and hence the utmost endurance. For the most part they possess camels only and thus are not limited in their movements.

The Reguibat, who number between 20,000 and 30,000, range over almost 600,000 sq km in the western desert including the province of Rio de Oro, and northern and middle Mauritania. Until a few years ago many families travelled 1,000 km or more in a year with their herds in search of pastures. They were originally sedentary cultivators and semi-nomads herding sheep in south Morocco. After their victory over their principal rivals at the beginning of this century they began to spread out. Once peace was definitely established in 1934, with the occupation of Tindouf in western Algeria by the French Army, they soon became the owners of the largest herds of camels. This happened 100 years after the start of the French penetration into northern Africa. In 1971 families were encountered who still possessed 2,000 camels.

The maintenance of the fragile ecological balance in the desert calls for extreme mobility and endurance from the men and the herds. The Reguibat and their particularly hardy types of camels respond well to such exigencies.
Grazing behaviour

Ecological, ethological and physiological investigations have shown that of all domestic animals the camel is best adapted to desert conditions. Its superiority is obvious under extremely harsh living conditions, when food and water are scarce. Such an ecological situation was experienced over six summers and especially the dry summer of 1973, which brought the worst drought for over 50 years. In general, camels suffered less from the drought in the Sahara than other domestic animals. According to a census conducted by the Food and Agriculture Organization of the United Nations in Niger in 1973, there were total losses of cattle, and 50 percent losses of sheep and goats, but only 20 percent of camels succumbed (FAO, 1977).

Camel grazing provides the most rational utilization of desert vegetation. It is entirely different from that of intensively grazing sheep and goats and slow moving cattle. Camels never overgraze. No matter what the quality or density of the pasture, they move constantly taking only small portions from any plant. Only certain small plants, growing separately, are eaten almost entirely. By contrast, sheep graze down to the roots and goats may climb into the trees. Camels behave rather like wild ruminants. They disperse widely during grazing, especially under drought conditions. During the 1973 drought many animals grazed alone, even two year olds which normally stay with the dam. During that summer no grass was left in middle Mauritania. Everything was eaten out by the goats and sheep maintained by semi-nomads or sedentary people.

In such conditions, and provided that man does not interfere with natural movement, the camels will spare even extremely poor vegetation. During the drought they kept on moving in their usual manner existing on acacia twigs and dry bushes. Controlling their movement would have conserved energy and allowed them to obtain more feed but the vegetation would have been seriously en-
dangered. The Mauritanian nomads know this very well. When vegetation becomes sparse, they leave the herds entirely on their own to find sufficient feed to survive, instead of herding them as is usual at any season to prevent them from escaping or being stolen.

Camels are very attached to their home region which covers a very large area where nomadism is on a large scale. Removed to regions unknown to them, they may try years later to return to their original area, which may be 1 000 km distant. For this reason, displaced animals may be difficult to herd. Females often attempt to return to the region where they first bred. Nomads like to buy camels before they have had the first calf. Camels have been found to escape to remote feeding-grounds, which they had kept in "good memory", and to cover 100 km in 24 hours without stopping (Denis, 1970).

It is no exaggeration to state that, under normal grazing conditions with unrestricted movements, the camel behaves as a conservator of desert pastures. In areas grazed by camels only, there exists a certain balance between the possibility of regeneration of the plant and the feeding intensity of the animal. In Mauritania, 7 areas of pasture were protected by UNESCO and IFAN (Institut Fondamental d' Afrique Noire) for several years. It was observed that the grasses which, in the West, form an important part of the camel's feed, grew better outside the areas where they were normally grazed, just as a meadow grows better when cut regularly. However the trees, which in the western and northwestern Sahara form a small but important part of the feed, grew better when they were temporarily protected.

Diet selection

The camel shows seasonal food preferences and normally leaves one part of the vegetation untouched. In the whole region about 200 fodder plants, mainly perennials, were identified, but more than 15-20 were rarely found
in any one pasture area. In many pasture areas of Mauritania there are not more than 5-10 plant species in summer. In the biggest sand area of the Sahara, the Majâbat al-Koubra in Mauritania, which extends over 1 000 km from Chinguetti to the southeast, Monod (1958) walked for a whole week in almost pure Aristida pungens populations.

In most pastures one or two species are favoured above the others and more of them is eaten. Of the many examples observed two are mentioned: the annual plant Diplotaxis pitardiana represented almost one-third of the total food intake in a rich spring pasture composed of about 40 fodder plants. In autumn in the western Erg near Beni-Abbès, the halophyte Cornulaca monacantha, among 8 species constituted 65 percent of the total food intake. It is often difficult to state which plants are really preferred, as distribution is very irregular and some highly palatable plants may be very rare, while some lesser appreciated species are abundant and are eaten in much higher proportions. Almost half the fodder plants in one plant community were barely touched; they comprised less than one percent of the total quantity of plants taken.

Certain plants were eaten in almost the same proportions all the year round. In northwestern Sahara these were Pituranthos chloranthus, Anvillea radiata, Rhanterium adpressum, and Randonia africana. Other plants are eaten only during one or two seasons and very little for the rest of the year. A very typical Chenopodiaceae, of the northwestern hamadas, Anabasis aretioides, often forms monospecific pastures and, although it is hard and dry and is supposed to wear out the teeth, it is one of the plants most eaten in summer and autumn, even where it is associated with about 15 other fodder plants. The dry grass Aristida plumosa represented 40 percent of the total food intake in the same region in summer. Other species, for example Farsetia hamiltonii, Gymnocarpos decander, Helianthemum lippii, and Launaea arborescens were only eaten in one or two seasons.
Annuals are generally preferred to perennial plants, but seasonal food preferences do not always depend on the moisture content of the plant, as the above-mentioned examples demonstrate. One of the most interesting fodder plants is *Aristida pungens* because of its abundance and long survival. It dries up quickly after the temperature first rises in spring; it covers immense dune areas in Mauritania and western Algeria where it is almost the only food available for 4 to 5 months. The dry stalks and leaves which the camels eat as well as the flowers are supposed to have a high nutritive value. Provided the camels are regularly watered they can thrive almost exclusively on this diet in summer.

Herds were observed leaving dense green pastures of *Calligonum comosum* and *Balanites aegyptiaca* in May, both of which plants are highly palatable, in order to reach distant dune pastures which contained only completely dry tufts of *Aristida pungens*. Other grasses, too, are selectively grazed in the dry state. *Aristida plumosa* was preferred to 17 other fodder plants on the hamada in summer near Beni-Abbés, though it contained no more than 38 percent of water. *Panicum turgidum*, one of the most typical grasses in sandy depressions, was preferred completely dry by the camels after they had been watered.

Certain species, growing as well in the dunes as on the hamada, may be more appreciated in one biotope than in another. In the Beni-Abbés region *Randonia africana*, a very common Resedaceae, was eaten much more in the dunes than on the hamada, though there were other highly palatable plants.

Camels are very fond of halophytes which are generally rich in protein and represent a very valuable food. In the western Sahara *Nucularia perrini* is one of the best fodder plants. In the northwest there are *Anabasis aretioides* and *Atriplex halimus*, the latter being the most commonly eaten in a spring pasture with 25 other fodder species. In both northwestern and western Sahara, *Cornulaca monacantha* growing on sandy terrain, and
Traganum nudatum growing in sandy and stony soils, are also frequently selected. They quickly provide the camel with its daily requirement of dry matter.

It is surprising how much the camel relishes spiny plants. In the regions studied they constitute a high proportion of the feed intake. The camel can obtain as much feed from very spiny plants as from tender ones, thanks to the long papillae of the palate, the mobile lips and the ability to open the mouth wider than any other ruminant animal.

Feed consumption

How is it possible to determine the camel's feed consumption? This was the major question when I started studying the camel's ecology in 1954. Observation of the grazing herds showed that the size of a bite of plant matter is rather constant for each plant species, and for any given type and quality of pasture. Some 150 free-grazing camels were observed over a total of 500 hours; sometimes the same animal was observed continuously for 8 hours. By counting the number of bites, and weighing from each species the plant matter corresponding to the size of the bite, it was possible to calculate approximately the amount of food ingested. This appears to be the only method possible which takes into consideration the normal grazing habits of the camel and the most irregular distribution of the vegetation. It also provides an accurate account of the composition of the diet, the fodder selection and the water which the camel obtains from the feed in a day, as the water content of all plants eaten was regularly determined.

The camel has a very low food requirement compared to its normal body weight, which is 350 - 500 kg. Various authors have stated that dromedaries need 30-50 kg of fresh food daily. This may be true of hard-working animals in semi-arid regions. In these areas studied, free-grazing camels receive no extra feed. They eat
30-40 kg of fresh matter rarely and then only on pastures which are composed of either annual plants after abundant rainfalls or of halophytes. These pastures contain up to 80 percent of water which corresponds to 8-12 kg dry matter (DM).

Although a camel spends 8-10 hours a day grazing, irrespective of pasture quality, the intake rarely exceeds 10-20 kg i.e. 5-10 kg DM. Camels generally consume 6-7 kg DM a day which is sufficient to perform the standard work during a 24 day trip in summer when they transport 120 kg for six hours a day at a speed of 5 km/h. Such camels received no extra food and yet were able to maintain an average pace of 10-20 km/h during the last day and showed no sign of fatigue at the end of the journey. In fact the amount of dry matter obtained was only of slightly lower quantity to that obtained in a rich pasture of annual plants containing 80 percent water.

Camels can survive for several months on a daily ration of no more than 5 kg DM. This was their usual intake when eating Aristida pungens with a density of 5-10 percent, because the flower as well as the tough points of the green stalks and the dry stalks are eaten very slowly. Judged by constitution and performance, dried up Aristida pungens seems to be no less beneficial than annual plants, of which the camel must eat six times as much in order to obtain the same amount of dry matter.

During the drought in middle Mauritania in the summer of 1973 the camels lived on dried acacia points. In eight hours of grazing they only obtained 2 kg, the lowest quantity the author has ever observed. This seemed to be the minimum subsistence requirement of a desert camel over a period of time, and this was the only occasion on which an extra ration of 4 kg of dry Aristida grass was given to each of the baggage camels during the 12 days journey, when each had to carry about 100 kg for several hours a day.

The nomads say that camels can subsist for a time
on an amount of 2 kg of dry *Aristida pungens* which is more nutritious than dry acacia twigs.

West Saharan camels, which require little fodder, are particularly hardy types. In former times they covered great distances on raids, and nowadays in search of feeding grounds. Feeding entails for them constant exercise which keeps them fit.

As already indicated, they consume great quantities of spiny plants. In the region studied there are only two species of acacia; *Acacia tortilis* spp. *raddiana* and *Acacia ehrenbergiana*. In northern Mauritania, where the first species is particularly abundant in the numerous wadis, the nomads confirmed that camels ate green acacias for several months in the summer without frequently watering. An excellent diet is acacia mixed with *Panicum turgidum*, a very common association to be found in dry river beds. The quantity of acacia which a camel normally consumes varies from about 100 g - 1 kg/h DM depending on whether the points of the twigs are very dry and spiny or young and tender.

In Mauritania and Algeria, another common spiny plant is *Launaea arborescens*, which grows in sandy wadis and depressions. It was one of the best liked plants in autumn and spring. The camel always obtains sufficient nutrition where this plant is dominant.

The longest and thickest thorns a camel is able to ingest are found on the subtropical tree *Balanites aegyptiaca*, which is very common in Mauritania. Many times the camel has been seen to eat 10 cm long points of twigs with a dozen spines up to 10 cm long. Generally the camel takes very small bites weighing between 1-5 g from those plants which are spiny, woody or prickly. On the other hand bites taken from annuals, lush green twigs or succulent halophytes may weigh between 10 and 20 g. The number of bites taken in one hour varies between 200 and 700.
While searching for food camels frequently wander 20-30 km in a day. If temperatures do not exceed 25°C they will graze continuously for 8-10 hours. As temperatures rise, they rest for longer periods during the hottest hours of the day. This is particularly so in the dunes, where radiation from the soil is very high. Herds which are allowed to feed during the night will rest for the entire day.

Freedom of movement is essential for the welfare of both the animals and of the vegetation. Camels which have their forelegs tied to prevent them from escaping will concentrate on following the herd rather than the search for food. The nomads know that their animals thrive best if they let them graze freely. A good nomad will prefer to make the effort to run after his animals instead of keeping them in a limited area for his own comfort. Many Saharan tribes camp at a well and let their herds roam about freely in summer, knowing that the camels are accustomed to returning to the same well during the five months period of watering.

During the 500 hours spent watching camels on the pasture, the author could rarely sit down for a quarter of an hour without losing her camel. When the nomads are migrating, they usually fasten the forelegs of their camels together so that they cannot go too far while they are feeding. In this way newly acquired animals are also prevented from escaping. Nevertheless, baggage camels which had their forelegs fastened at night were found at a well which was known to them 10 km away. There was another well near the rest site. French members of the former military camel corps recounted how a group of camels, two of which had their forelegs tied, travelled 110 km in 40 hours.

In the study area camels were found to eat 2-4 tons of forage (dry weight) per year. This is a small quantity in comparison with the food reserves which generally exist in middle Mauritania. Many regions there were underutilized except in particularly dry years. A great number of
measurements to evaluate the productivity and carrying capacity were carried out on some of the typical west Saharan pastures. *Aristida pungens* and *Panicum turgidum* were studied particularly because they are so extensive in their distribution. They are among the most important fodder plants that camels eat and they are consumed green as well as dry throughout the year. The measurements showed that the quantity of plant matter produced on such types of pasture is much higher than that eaten by the camel (Gauthier-Pilters, 1969).

The great mobility and wide distribution of men and camels in summer means that there are never big herd concentrations. In summer it is rare to meet more than 500 camels in a day at the same well. By contrast, concentrations on pastures and on wells in northern Kenya appeared much higher and it is common for 1 000 camels to gather at one well. It must be pointed out that the grazing and watering facilities in some of the regions in northern Kenya are much better than those found in the western Sahara.

Water intake

The amount of water which a camel obtains from the feed varies depending on the season and type of pasture. In the Beni-Abbé region, the camel ingested 4.5 litres per day on an autumn pasture where acacia dominated, 13 litres on spring pastures on the rocky plateau containing a few annuals, 24 litres on pastures in a mountain valley with large quantities of annuals and 30 litres on salty pastures. On dry *Aristida pungens* pastures in the western Sahara the water obtained from the food was less than one litre per day. In the western Erg in southern Algeria, however, the camel obtains 15-20 litres per day from a great number of evergreen bushes in summer. This enables it to go at least one week without drinking even when the maximum daily temperature exceeds 40°C. In the western Sahara the camel rarely obtains more than 6-7 litres in its daily
feed during the hot season and access to water becomes particularly important.

The minimum quantity of water which a camel requires during the cool season is not known. Camels which consumed feed containing 4.5 litres of water in November in temperatures reaching 24°C, did not return of their own volition to the well. Those taken to the well drank only very small quantities.

Apart from the extremely dry years, the camel can go from October till April or May without drinking water. Most fodder plants at that time of the year were found to contain 50-60 percent water. In the cooler months camels can therefore range over those wide areas which are situated far away from wells and which have not been used during the hotter months being inaccessible to other domestic animals obliged to drink more frequently.

In the summer the camel can remain without water longer than any other domestic animal because it has a very low rate of water loss and an exceptional tolerance to dehydration. Precisely how long a camel can go without drinking depends on a number of considerations: meteorological factors, quantity, quality and water content of the food ingested, the age of the animal, and its work load. In summer not only the daily maxima but also the night temperatures are of great importance. Sudden climatic changes can modify drinking behaviour. An occasional rainfall or cooler nights result in camels going several days more without drinking, even though maximum temperatures are invariably high.

It was observed that camels returned to the well when the air temperature reached 30-35°C and that the intervals between drinking became short and regular only for about two months when the maximum temperatures exceeded 40°C almost every day. On salty pastures the camel will drink every day or two but otherwise the minimum interval will not be below 3-4 days, even when the
principal food consists of dry *Aristida pungens*.

Unguarded herds drink less often than guarded ones because they eat more. Indeed, well fed animals will drink the largest quantities at a time. They can stand a loss of 40 percent of their normal body weight and well over one-half of their dehydrated weight. They do not lose appetite until they have lost approximately 30 percent of their weight. Schmidt-Nielsen's laboratory camels (1964) stopped eating when they had lost 20 percent of their weight.

The water consumption of about 600 individuals has been checked separately on more than 800 occasions. Each camel drank as much as it wanted, which is an unusual situation when group-watering camels on overcrowded wells. The camel has an enormous drinking capacity, taking within 10 minutes more than 1/3 of its weight of water at a speed of 10-20 litres per minute. The maximum quantity taken in one draught was observed several times to be 130 litres. Thus even high water loss can be replaced by a single drink allowing more time for grazing. Some free-roaming animals, after a week without water, took 200 litres within a few hours in two or three drinking sessions. Such quantities are exceptional, but they show to what degree the camel under natural conditions voluntarily resists dehydration. In summer, most animals drank 120-140 litres, the average quantity per day during the hottest season being 20-30 litres. The most frequent dehydration period noted was 5 days. In northern Mauritania where the nights are much cooler, the camel needs less water and drinks less often.

The ability to compensate high water loss in a minimum of time is of great importance, for this enables the camel to reach remote pastures without having to graze the area in close proximity to the well. The well areas are thus spared for the animals which cannot walk so far. In turn the gain in feeding time has a favourable influence on the drinking capacity, as well-
fed animals, eating at least 5 kg of dry matter per day are able to compensate completely for their water loss. A high drinking capacity also allows a camel longer to dehydrate and so it can stay longer at pasture, can utilize a larger range and expends less energy in walking to the well.

Schmidt-Nielsen and his co-workers (1956) stated that camels kept under laboratory conditions reduced their water loss during dehydration. In the field this author observed that the quantity of water ingested (average/day), which corresponds to the quantity of water lost through urine, faeces and evaporation, decreased only when the intervals between drinking exceeded 4 days. It was reduced by half after 8 days without drinking.

Food and water intake are closely interrelated. It was noted that during the exceptionally dry summer of 1973 the camels, feeding sparsely, drank only about half of the quantity taken in other years by normally fed animals in the same region under the same heat stress. Although water intake from feed was extremely low the animals interrupted drinking more frequently than well fed animals. Most of the underfed camels seemed unable to drink more than 20–25 percent of their body weight.

Animals previously in good condition, managed to survive such low levels of food and water intake. However, those which were overworked or insufficiently fed owing to a loss of mobility of their owners and were weakened before the summer of 1973, had reached the limit of their resistance. Many animals which had come to the well and which lay down before or after drinking, were too weak to get up again and died. Others died near the well because there was no one to water them, since only the most important wells had a permanent team of people to draw the water.

Different behaviour patterns serve to reduce water loss. In summer, resting camels face the sun; they remain
all day on the same spot, adjusting their position to the sun. In this way they expose the smallest body surface to the sun. They also huddle in compact groups, especially on sandy soils, which have high radiation. There is less heat flow from the neighbouring camel than from the environment; Schmidt-Nielsen showed that the external temperature of the fur directly exposed to the sun may rise to $80^\circ$C.

The role of nomadism for camel breeding

Although camels are easy to herd in large numbers because of their gregarious sense and their docility, sound management requires the cooperation of the whole nomad community, utilizing many generations of experience. Vegetation is particularly endangered by a loss in mobility of the nomads. This loss in mobility is caused mainly by the impact of technical civilization which has spread further and further into the desert during the last 20 years. Construction sites, mining areas, roads, railways and settlements offer easy feed and water supplies so that the nomads and their herds remain much longer at the same spot than previously. This is the reason why in many places the recent droughts have led to the disappearance of nomadism. Droughts have always existed obliging many nomads to settle down, but never for long. As soon as possible they built up a herd again and returned to the desert.

There is no doubt that in settling down the nomad soon loses all those qualities which enabled him to survive in the desert. After a while, even if given the opportunity, these people would not want or be able to take up nomadic life again. Many former nomads were questioned in the immense refugee camps of Mauritania's capital, Nouakchott, in 1976. Most of the young men did not want to return to nomadic life even if they were given some camels, while almost all the men above 40 years of age did. Nevertheless, industry does not supply sufficient permanent employment. In Mauritania as a
consequence of the drought and the political troubles in the North, all the working camps along the railway line leading from the mining centre to the Atlantic Ocean have grown into huge slums, where only very few people find work.

In supplying the needs of these people, evolution toward settling down cannot be avoided, even though they were entirely satisfied and proud of their traditional way of life which is so much in equilibrium with the desert. It is an error to believe that one can modify nomadism without provoking its decay.

Technical help should be put at their disposal to encourage them to remain in the desert, since camel nomadism is not only the optimal, but also the only means of utilization of large desert areas. A deep knowledge of the camel's natural living conditions in as many regions as possible is indispensable to organizing help which is appropriate to their needs. These needs are not necessarily the same for all arid and semi-arid regions.

As far as the western Sahara is concerned, the main help should be toward a better utilization of water resources. During the several thousand hours spent at desert wells, the author became aware of the great inadequacies of wells which are too small, too big or which lacked proper equipment. This strongly disadvantaged both the welfare of the herds and the vegetation. With regard to the existing food resources a number of medium wells at reasonable distances are far more useful than a few big wells which attract many more herds than the surrounding pastures can carry. Better equipment at the well, which can be obtained with relatively small funds, would help to keep the water clean, and prevent wastage. Better designed wells can ease the task of the nomad, making his life more attractive, or at least less painful. By accelerating the watering process overgrazing can be diminished and the camel can achieve all the advantages already mentioned such as the gain in feeding time, complete rehydration etc,
Reserve feed stocks should be available for drought periods. They proved to be very helpful in summer 1973 in the former Spanish Sahara, since they saved most animals from starvation and prevented the nomads from settling without any hope of finding work. Last but by no means least, a veterinary survey and veterinary service, which were virtually non-existent in the areas visited, would be a further great help.

Encouraging the nomads to settle means a decrease in desert camel breeds and a deterioration of the desert pastures. Only the camel is able to convert this fodder into meat and milk without destroying the vegetation. Though camel meat may be less valued than that of sheep, goats and cattle, it must be kept in mind that large desert areas can only be exploited by camels. In a world suffering from hunger no food resources should be neglected, especially in the desert.

REFERENCES


THE PLASMA ELECTROLYTES AND MINERALS OF NORMAL CAMELS IN THE SUDAN

A.G.A. Wahbi, Salaheldin E. Abdelgadir, N.A. Awadelseid and O.F. Idris

Summary

This study utilized ninetysix male, clinically healthy, adult camels from the Tambooll grazing area.

The plasma collected was analyzed for certain electrolytes and minerals and the results are discussed in comparison with reports from the Sudan and elsewhere.

It is felt that, as far as the electrolytes and minerals studied here are concerned, the Tambooll grazing area contains a satisfactory level since the camels sampled were solely fed on pasture.

Introduction

In a tropical country like the Sudan where the majority of livestock are reared under range management or nomadic conditions, mineral investigations are of great importance. In spite of this, reports of the occurrence of nutritional disorders are rarely published and there is an underestimation of mortality due to these disorders because their incidence is masked by the major contagious diseases.

Studies on copper and iron in the blood and tissues of cattle, sheep, goats and camels of the Sudan, as well as soil and pasture analyses, have been reported (Tartour, 1975; Idris and Tartour, 1975; Idris et al., 1976; Wahbi and Idris, 1977 a, b). Other contributions have been forthcoming on camel serum sodium, potassium and calcium (Hoeller and Hassan, 1966; Idris and Tartour, 1977), on camel serum iron and serum iron-binding capa-
city (Tartour and Idris, 1970), and on *Trypanosoma congolense* infected cattle (Tartour and Idris, 1973).

There are also reports on iron, inorganic phosphates, calcium, magnesium, sodium and potassium in camel plasma by Soliman and Shaker (1967); Ghosal et al. (1973); and Zein El Abdin et al (1975).

This work was undertaken to investigate some electrolytes and minerals in camel plasma from the Butana area and to shed some light on the mineral status of camels in that part of the Sudan.

Materials and methods

Heparinized blood was collected from the jugular veins of ninety-six male, clinically healthy, adult camels from the Tambool grazing area in Gezira Province. Plasma was separated by centrifugation and stored at -20°C for further analysis.

The plasma samples were analyzed for the following constituents:

- Sodium (Na) and potassium (K), by the flame photometry method (Evans Electroselenium, Ltd.) as described by Varley (1969).

- Calcium (Ca), in accordance with Ferro and Ham, (1957).

- Magnesium (Mg), by the method described by Spare, (1962).


- Copper (Cu), was estimated by atomic absorption (Pye Unicam, Ltd., model SP 191) where air and acetylene pressures were 4.5 - 5.5 and 1.0 - 1.5 litres/minute respectively, in accordance with Dawson et al. (1968).
- Iron (Fe), was done according to Trinder (1956), following Cat. No. 124214 (Boehringer Mannheim GmbH Diagnostica).

- Total iron-binding capacity (TIBC) was estimated according to Ramsay (1958), following Cat. No. 124 222 (Boehringer Mannheim GmbH Diagnostica).

Results and discussion

The mean values and ranges for the parameters studied are shown in Table I.

Camels in the Sudan are maintained under an extensive system of husbandry. The nomadic herds are constantly on the move from one place to another, and areas of deficiency are soon compensated for, while areas of toxicity are avoided by herdsmen. Any shift of camel production to a semi-intensive system, requires close attention to mineral studies since losses from mineral deficiencies or toxicity are considerable and may contribute a high percentage of the total losses from nutritional causes in tropical countries (Mukhtar, 1971).

Plasma sodium in the animals investigated in the Butana area was found to be within the accepted ranges of normality. 75 percent of the animals had sodium levels above 140 mEq/l, and 3 percent had values less than 130 mEq/l. This is in agreement with the values obtained by Hoeller and Hassan (1966) but is lower than those quoted by Idris and Tartour (1977). The results are in agreement with those reported by Ghosal et al. (1973) and Zein El Abdin et al (1975).

The mean plasma potassium level was 5.30 mEq/l and this also is within the accepted normal values, and is in agreement with the values reported by Ghosal et al. (1973); Zein El Abdin (1975); and Idris and Tartour (1977).
The mean plasma calcium level was 9.2 mg/100 ml which is within the reported normal range, and accords with Hoeller and Hassan (1966) for serum collected from camels in western part of the Sudan. Less than 2 percent of the animals investigated had a plasma Ca level below 8 mg/100 ml. However, no clinical evidence of disease due directly to Ca deficiencies was encountered during the investigation.

Serum or plasma inorganic phosphate has not been reported in camels in the Sudan. The value obtained here was 5.3 mg/100 ml with a range of 3.9 - 6.8 mg/100 ml. Almost 5 percent of the sampled animals had an inorganic phosphate of less than 4.8 mg/100 ml.

The plasma magnesium level in camels in the Sudan is not reported. However, the mean values obtained here were within the accepted ranges of normality (1.8 - 3.1 mg/100 ml) quoted by Doxey (1971). It seems that the magnesium level in the plasma of the camel in Sudan is satisfactory since there was never any indication either clinically or biochemically that there was any abnormality attributable to derangement of serum Mg level. Our results are higher than those reported by Ghosal et al. (1973) and Soliman and Shaker (1967). This could be due to nutritional, environmental or breed differences.

Among the trace elements in the Sudan, attention was focussed on Cu and Fe. Earlier Cu determinations done on camels, sheep and cattle were on whole blood and tissues (Tartour, 1975; Idris and Tartour, 1975; Idris et al., 1976 and Wahbi and Idris, 1977 a, b).

Copper mean value, obtained here was 118.3 μg/100 ml and lies within the normal range for ruminants. Since the animals were fed on pasture, it may be suggested that Butana area pasture is copper-sufficient by contrast with the Bahr el Arab zone and some other parts of the country which are either critical or deficient for the nutrition of animals (Tartour, 1975; Idris and Tartour, 1975).
Mean values for serum iron and total iron binding capacity as reported here were comparable with those reported by Tartour and Idris (1970).

<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td>Sodium</td>
<td>147 ± 4.2 mEq/l</td>
<td>(129.3 - 160.7)</td>
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<tr>
<td>(Na)</td>
<td></td>
<td>(129.3 - 160.7)</td>
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<tr>
<td>Potassium</td>
<td>5.3 ± 0.43 mEq/l</td>
<td>(3.6 - 6.1)</td>
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<td>(K)</td>
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<td>(3.6 - 6.1)</td>
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<tr>
<td>Calcium</td>
<td>9.2 ± 0.99 mg/100 ml plasma</td>
<td>(6.3 - 11.0)</td>
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<tr>
<td>(Ca)</td>
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<tr>
<td>Magnesium</td>
<td>2.5 ± 0.28 mg/100 ml plasma</td>
<td>(1.8 - 2.9)</td>
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<td>(Mg)</td>
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<td>(1.8 - 2.9)</td>
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<tr>
<td>Inorganic phosphates</td>
<td>5.3 ± 0.94 mg/100 ml plasma</td>
<td>(3.9 - 6.8)</td>
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<td>(I.P.)</td>
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<td>(3.9 - 6.8)</td>
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<tr>
<td>Copper</td>
<td>118.3 ± 28.8 ug/100 ml plasma</td>
<td>(60 - 172)</td>
</tr>
<tr>
<td>(Cu)</td>
<td></td>
<td>(60 - 172)</td>
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<tr>
<td>Iron</td>
<td>98.5 ± 19.0 ug/100 ml plasma</td>
<td>(62 - 132.9)</td>
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<tr>
<td>(Fe)</td>
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<td>(62 - 132.9)</td>
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<tr>
<td>Total iron-binding</td>
<td>320.8 - 61.9 ug/100 ml plasma</td>
<td>(198 - 443)</td>
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<td>capacity (TIBC)</td>
<td></td>
<td>(198 - 443)</td>
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REFERENCES


Spare, P.D. 1962 Medical laboratory Technology and Clinical Pathology. Publisher W.B. Saunders Co.


Trinder, P. 1956 J.clin. Path. 9, 170.


SOME BLOOD AND PLASMA CONSTITUENTS OF THE CAMEL

Salaheldin E. Abdelgadir, A.G.A. Wahbi and O.F. Idris

Summary

Studies were carried out on 96 male Sudanese dromedaries. They were adult animals that had fed entirely on grazing pasture around the Tumbool area in Gezira Province. The animals were clinically healthy and at post mortem were found to be free from disease.

Studies were made on certain blood and plasma constituents. The results report mean values for plasma cholesterol, uric acid, creatinine and whole blood glucose. In addition mean values for total protein, albumin, globulin, urea, total lipids and bilirubin are reported.

Introduction

Of all the livestock in the Sudan, the camel has received the least attention. Studies reported on camel serum constituents have been concerned with urea (Idris and Tartour, 1970), and total protein, albumin and globulin fractations (Hoeller and Hassan, 1966; Hassan et al., 1968; Idris and Tartour, 1977). Notable contributions to the literature have been made by Soliman and Shaker (1967), Jatkar et al. (1962), and Zein El-Abdin et al. (1975).

There are few studies on plasma cholesterol, uric acid, creatinine and blood glucose in camels in the Sudan. The normal ranges have been investigated and are recorded.

Materials and method

The material consisted of 96 male Sudanese dromedary
camels. These were adult animals that had fed exclusively on pasture around Tumbool in Gezira Province, during the rainy season of 1979. The animals were clinically healthy and at post mortem following slaughter were found to be free from disease.

Blood samples were collected from the jugular vein in clean McCartney bottles containing heparin. The samples were centrifuged; plasma was transferred to other bottles and stored at -20°C to await analysis.

The following analyses were performed:

Total protein - determined by the Biuret method, according to King (1964).

Albumin - as described by Bartholomew and Delaney (1964).

Urea - estimated according to Evans (1968).

Total lipids - as described by Frings and Dunn (1970).

Cholesterol - in accordance with Varley (1969).

Uric acid - as described by Caraway (1955).

Creatinine - determined according to Owen et al. (1954).

Bilirubin - estimated as described by Malloy and Evelyn (1937).

Blood glucose - determined according to Varley (1969).

Globulin - calculated as the difference between total protein and albumin.

Results and discussion

The mean value for the constituents studied are shown in Table 1.
Mean values for plasma total protein, albumin and globulin found in this study were 7.3, 3.8 and 3.5 g/100 ml respectively. Nearly similar values were reported by Soliman and Shaker (1967) and Idris and Tartour (1977); but Perk and Loble (1961) and Hoeller and Hassan (1966) reported higher values, while Ghosal et al. (1973), Kumar et al. (1961), Jatkar et al. (1962), Bhargava et al. (1964) and Zein El-Abdin et al. (1975) reported lower values. These discrepancies may be due to variations in food intake, age, and environmental conditions.

Reports on blood glucose in camels in the Sudan are lacking in the literature. The level, which is reported here for the first time, is 49.8 mg/100 ml. This value is in agreement with the level reported by Albriton (1952). However, Lal et al. (1962) and Soliman and Shaker (1967) quoted much higher concentrations.

It appears from the present findings that individual variations of plasma urea in the camel are quite large. However, the animals examined have revealed ranges similar to those reported elsewhere (Idris and Tartour, 1970). While Soliman and Shaker (1967) reported lower values, Zein El-Abdin et al. (1975) quoted higher values but the methods of analysis were different.

The mean value for plasma total lipids reported here was found to be 195.2 mg/100 ml which is much lower than the value reported by Zein El-Abdin et al. (1975). This is understandable if we consider the different methods applied and the feeding regime.

Studies pertaining to plasma cholesterol in livestock in the Sudan are lacking in literature. Comparing our results with those reported elsewhere (Zein El-Abdin et al., 1975), our values appear to be much lower. This may be due to nutritional, environmental and technical variations.

Similarly, data on plasma uric acid in Sudanese camels are lacking in the literature. Our results are
lower than those reported by Zein El-Abdin et al. (1975).

Mean total plasma bilirubin found in this study was 0.32 mg/100 ml. This is higher than the value reported by Soliman and Shaker (1967) and Obeid (1969). This might be due to variations in methodology.

Plasma creatinine levels have not previously been reported from the Sudan. The mean value obtained here was 1.9 mg/100 ml which is much higher than that reported by Soliman and Shaker (1967).

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<td>Total protein</td>
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<td>Albumin</td>
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<td>Globulin</td>
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<td>Glucose</td>
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<td>Urea</td>
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<td>Bilirubin</td>
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A NOTE ON THE HAEMATOLOGY OF ADULT SUDANESE DROMEDARIES

Salaheldin E. Abdelgadir, A.G.A. Wahbi, and O.F. Idris

Summary

Blood samples of ninetysix clinically healthy adult male Sudanese camels from the Tumbool area were used in this study.

A complete haemogram was made and the results are discussed in comparison with other reports from India, Egypt, Sudan and Iran.

Introduction

Studies on camel haematology have been made in India (Banerjee et al., 1962; Banerjee and Bhattacharjee, 1963; Lakhotia et al., 1964; and Ghosal et al., 1974), Iran (Ghodsian et al., 1978), Sudan (Hoeller and Hassan, 1966), and Egypt (Soliman and Shaker, 1967).

Haematological studies so far carried out on the camel in the Sudan are far from being complete. More information is needed on normal camel haematology.

Materials and methods

Haemoglobin (Hb), packed cell volume (PCV), red blood cells (RBC), white blood cells (WBC), differential leucocytic counts, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentrations (MCHC), were determined in the blood taken from ninetysix male Sudanese camels. These were adult animals that had been fed entirely by natural grazing around Tumbool area during the rainy season of 1979. They were clinically healthy and were
found to be free from pathological or anatomical abnormalities at post mortem examination in Tumbool slaughterhouse.

The blood samples were collected from the jugular vein in clean bottles containing heparin anticoagulant.

Haemoglobin concentration was determined colorimetrically as cyanmethaemoglobin according to Schalm et al. (1975). PCV was determined using a Hawksley microhaematocrit centrifuge. RBC and WBC counts were made using the improved Neubauer Haemocytometer (Hawksley and Sons, Ltd., England). The differential leucocytic counts were made on Leishman stained thin smear, and not less than one hundred cells were counted. MCV, MCH and MCHC were calculated from Hb, PCV and RBC values according to Schalm et al. (1975). (Table 1.)

Results and discussion

The overall mean was calculated for all the parameters studied and the results are shown in Table 1.

Comparing the Hb values in camels with those of sheep and dairy cattle in the Sudan, it has been found that Hb in camels is slightly higher (Wahbi and Idris, 1977 a,b); this does not apply to the stallion and the mare (Yassin et al., 1973). These findings agree with those of Banerjee et al. (1962).

The haemoglobin values agree with those reported by Lakhotia et al. (1964), and Ghodsian et al. (1978) in Indian and Iranian camels respectively; but they were lower than those obtained by Banerjee et al. (1962), and Soliman and Shaker (1967). In Sudanese camels our results agree with group (C), values obtained at the end of the dry season by Hoeller and Hassan (1966).

The PCV values obtained in this study were low as
compared to those reported by Soliman and Shaker (1967) on Sudanese camels, but they were in agreement with Banerjee and Bhattacharjee (1963). The discrepancy might be due to haemodilution as a result of water availability since the samples were collected in the rainy season.

Unlike the RBC of the other domestic animals, the camel cell is oval in shape. RBC counts reported here were slightly higher than those reported on Indian adult camels (Lakhotia et al., 1964; Banerjee et al., 1962), Iranian adult camels (Ghodsian et al., 1978) and Sudanese adult camels (Soliman and Shaker, 1967), but they were lower than those reported by Hoeller and Hassan (1966). This could be attributed to differences in techniques, breed, nutrition and environmental conditions.

Due to the large number of red blood cells in the camel, the mean corpuscular haemoglobin is low. However, the mean corpuscular haemoglobin concentration is high.

White blood cell counts obtained here were in agreement with Lakhotia et al. (1964) and Soliman and Shaker (1967). However, they were lower than the values obtained by Ghodsian et al. (1978); Hoeller and Hassan (1966) and Banerjee et al. (1962). This could be due to variations in the handling of the samples. Generally, the WBC count in the camel is the highest of all the domestic animals (Dukes, 1955). The percentages of neutrophils, lymphocytes and monocytes reported here were in agreement with Banerjee et al. (1962) but there were fewer eosinophils.
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<tr>
<td>Hb</td>
<td></td>
<td>11.1 ± 1.78 g/100 ml</td>
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<td></td>
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<td>(7.8 - 15.9)</td>
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<td>PCV</td>
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<td>30 ± 2.64%</td>
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<td>RBC</td>
<td></td>
<td>7.83 ± 1.31 x 10^6/cm mm</td>
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<td>(7.22 - 11.76)</td>
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<td>MCV</td>
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<td>40 ± 2.2</td>
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<td>(35 - 60)</td>
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<tr>
<td>MCH</td>
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<td>18.4 ± 2.1</td>
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<tr>
<td>MCHC</td>
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<td>46.4 ± 3.7%</td>
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<td>(36.5 - 50.9)</td>
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<tr>
<td>WBC</td>
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<td>13.23 ± 2.01 x 10^3/cm mm</td>
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<td>(11.15 - 16.5)</td>
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<tr>
<td>Neutrophils</td>
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<td>51%</td>
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<tr>
<td>Lymphocytes</td>
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<td>40%</td>
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<td>Monocytes</td>
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<td>4%</td>
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<tr>
<td>Eosinophils</td>
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<td>4%</td>
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<tr>
<td>Basophils</td>
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REFERENCES


COMPARATIVE BIOCHEMICAL STUDIES

B. Emmanuel

Summary

Urea, glucose, ketone body and fatty acid metabolism is compared between the camel and true ruminants. The extent of endogenous urea degradation is higher in the camel than in the sheep, goat or calf. Plasma glucose concentrations and glucose entry rates in the fed and fasted states are higher in the camel than in the sheep. The activity of 3-hydroxybutyrate dehydrogenase (E.C. 1.1.1.30) in the rumen epithelium and liver, and the levels of plasma ketone bodies are markedly lower in the camel than in the sheep. The rumen epithelium and liver of the goat and sheep oxidize more butyrate to ketone bodies and CO₂ than the camel, whereas the reverse case is true for the kidney. The depot fatty acids of the camel resembles more that of the deer than domesticated ruminants.

Introduction

The camel survives in habitats (tropical, arctic, and desert) unsuitable for true ruminants. Domesticated ruminants (cow, sheep, and goat) have a compartmentalized stomach consisting of rumen, reticulum, omasum and abomasum. On the other hand, the camel lacks the third compartment (omasum) (Hansen and Schmidt-Nielsen, 1957). In addition, the rumen epithelium of camelids is devoid of papillae (Vellenas et al., 1977), and both the rumen and reticulum contain in part glands (Pilliet, 1885; Hansen and Schmidt-Nielsen, 1957; Vallenas and Stevens, 1971; Vallenas et al., 1977). It is, therefore, reasonable to expect the camel to show some differences in metabolic processes. Very little work on the metabolism of the camel has been done. This presentation provides comparative data on urea, glucose, ketone
body, and fatty acid metabolism between the camel and true ruminants from the work performed as well as in the literature. Information on the metabolism of the camel may lead to livestock improvement in this species.

Urea metabolism

In ruminants, endogenous urea (originating from the liver) is transferred to the digestive tract in the saliva, through the rumen epithelium, and the wall of the lower digestive tract (Baily and Balch, 1961; Somers, 1961; Cosimano and Leng, 1967; Houpt and Houpt, 1968; Nolan and Leng, 1972). Subsequently, the urea nitrogen is partially assimilated into microbial protein, which in turn is hydrolysed in the small intestine, and the resulting amino acids are made available to the animal, thereby contributing to the nitrogen economy of the host. The extent of hydrolysis of endogenous urea in the gastrointestinal tract has been studied in ruminants tested on different diets (Ford and Milligan, 1970; Nolan and Leng, 1970; Robbins et al., 1974). The kinetics of urea metabolism are compared in camels given three levels of dietary protein (6.1, 9.6 and 13.1 percent). For comparison, sheep, goats and calves were fed on the diet containing 9.6 percent protein and kept under similar laboratory conditions.

Experimental

A total of 14 local female animals were used: two one-humped camels (Camelus dromedarius); four mature goats, four mature sheep and four calves aged 10 months. The animals were housed individually, and had free access to drinking water. Forage diets containing 6.1, 9.6 and 13.1 percent crude protein (Emmanuel et al., 1976) were offered to appetite to camels, and the diet containing 9.6 percent to remaining animals. Each diet was offered for a period of 30 days. To establish a steady metabolic state, during the last 5 days of each period
known quantities of the ration were given manually at 1-2 hour intervals.

The procedures used for the injection of radioactive urea, collection of urine, blood sampling, measurements of urinary and plasma urea concentration, and determination of urinary $^{14}$C-urea were those described by Emmanuel et al. (1976), and Emmanuel and Emady (1978). The kinetics of urea metabolism were computed as described by Emmanuel et al. (1976), utilizing the procedures of Zilversmith (1960), Cosimano and Leng (1967); Mugerwa and Conrad (1971), and Robbins et al. (1974).

Results and discussion

The kinetic of urea metabolism is presented in Table 1. With increasing levels of dietary nitrogen intake, plasma urea concentration, urea pool size, urea entry rate, and urinary urea excretion rate were increased in the camel. On the other hand, the extent of urea degradation calculated on the basis of urea entry rate, or dietary-N intake was reduced. Urea degradation rate was not influenced by the level of dietary protein. The relative constancy of these values suggests that a plasma urea-N concentration of 8.9 mg/100 ml, which was associated with the lowest crude protein intake (9.6 percent), is at or above the physiological limit of the rate of urea degradation within the digestive tract. These observations are in agreement with those of Robbins et al. (1974) for deer and of Mugerwa and Conrad (1971) for dairy cattle. In sheep, urea degradation reaches a plateau at a higher plasma urea concentration (Houpt and Houpt, 1968; Vercoe, 1969). The results suggest that increasing crude protein intake above 9.6 percent causes no increase in utilization of endogenous urea in the camel.

At the lowest level of dietary nitrogen intake, the average amount of urea degraded in camels was equivalent in terms of nitrogen to 145 percent of the die-
tary intake. Probably, the camels were mobilizing and utilizing tissue nitrogen, or nitrogen fixation occurred in the rumen as has been reported in other ruminant species (Elleway et al., 1971; Granhall and Ciszuk, 1971; Hobson et al., 1973). Jones and Thomas (1974) have shown that up to 750 mg nitrogen per day can be fixed in the rumen of the sheep. It is possible therefore, that when camels were fed the diet low in protein, nitrogen fixation made a relatively important contribution to the protein supply. Considering this issue from a different angle, the recycling of urea more than once during the experimental period could also result in such a high value.

No differences in plasma urea concentrations between species fed on the same dietary regimen were observed. It is likely then that in ruminants under a normal feeding system, plasma urea concentration primarily depends on dietary protein (nitrogen) content and its quality. The kinetics of urea metabolism in sheep, goats and calves were similar. On the contrary, the extent of urea degradation calculated on the basis of urea entry rate, dietary-N intake, and metabolic body weight was markedly higher in the camel, which supports earlier studies (Schmidt-Nielsen et al., 1957). The above findings are not surprising; factors including blood flow, and microbial urease activity in the digestive tract, and filtration and reabsorption of urea in the kidney affect urea degradation and excretion in ruminants. The camel receives very little protein from the vegetation of its natural habitat, therefore, it is likely that a mechanism more efficient for conservation of nitrogen exists in this animal as compared with other species of ruminants.

The parameters of urea metabolism in different mammalian species are tabulated in Table 2. In general, in all species studied with increasing levels of nitrogen intake, plasma urea concentrations increased, and urea entry and excretion rates in most cases were elevated. With the exception of the camel, urea degra-
dation rates were enhanced. The extent of urea degrada-
tion expressed on the basis of urea entry rate was
generally reduced. The extent of urea degradation per
unit dietary-\(N\) intake (last column, Table 2) was
higher in the camel. The daily rates of urea degrada-
tion per kg B wt\(^{0.75}\) found in ruminants are signifi-
cantly higher than those of monogastric animals
(Walser and Bodenlos, 1959; McKinley et al., 1970)
which reflects the high microbial population present in
the gastrointestinal tract of ruminants.

Regression of urea entry rate on plasma urea con-
centration (Fig. 1) demonstrates a highly positive rela-
tionship in different non-lactating, non-pregnant
ruminant species which are in the fed state. The data
on lactating cows (Mugerwa and Conrad, 1971) do not fit
this regression line. This correlation has been reported
to be true for other metabolites including glucose
Bergman, 1964; Bergman et al., 1974; Chandrasena et al.,
1979a), and lactic acid (Annison et al., 1963b; Depocas
et al., 1969; Issekutz and Allen, 1972) in ruminants
as well as monogastrics.

Glucose metabolism

Fermentation of dietary carbohydrates in the rumen
leads to production of volatile fatty acids (acetate,
propionate and butyrate) (Hungate et al., 1961) and
only small quantities of glucose are available for
absorption by the gastrointestinal tract. Ruminants
maintain a low blood glucose concentration (50-75 mg/
100 ml) (Bergman, 1963; White et al., 1969; Bergman et
al., 1970). Measurements of glucose entry rates (uti-
лизation rates ) in sheep nevertheless have been
found to be quantitatively only slightly less than in
the post-absorptive man and dog (Ballard et al., 1969)
exemplifying the significance of gluconeogenesis in
ruminants. Camels are however, able to maintain blood
glucose concentrations in the range of 100-140 mg/100 ml
(Kumar and Banerjee, 1962; Lal et al., 1962; Barakat
and Abdel-Fattah, 1970, 1971; Yagil and Berlyne, 1977) despite showing a true ruminant pattern of digestion (Vallenas and Stevens, 1971). Glucose utilization rates are compared in the fed and 72 hour fasted camels with that of sheep under the same conditions of feeding and housing.

Experimental

Two male one-humped camels (*Camelus dromedarius*) (300 and 320 kg) and two wether sheep (*Ovis aries*) (35 and 35.5 kg) were housed individually and fed daily a diet of 6 and 2 kg of alfalfa hay, respectively. Water was available free of choice. Experiments were performed on animals under the continuous feeding regimen and after an interval of 2 weeks the same observations were conducted on animals fasted for 72 hours. The animals were previously accustomed to handling, blood sampling and to the experimental regimen. The procedures used for maintaining a steady metabolic state, continuous infusion of radioactive glucose, blood sampling, measurements of plasma glucose concentrations and activity were as described by Chandrasena et al., 1979a).

Results and discussion

The results are shown in Table 3. Based on metabolic body weight, glucose entry rate in the camel was 1.5 times higher than that of the sheep. Plasma glucose concentration in the camel was considerably higher than in the sheep. In both species, starvation lowered glucose entry rate by an order of 40 percent. Brockman et al. (1975) obtained a 50 percent decrease in glucose entry rate after 72 hours of food deprivation in sheep, while Bergman (1963) found a decrease of 35 percent after 120 hours of food withdrawal. Similar results have been obtained for a variety of monogastric species: human volunteers (Kriesberg et al., 1970); dogs (Cowan et al., 1969); rats (Defreitas and Depocas, 1969), and horses (Evans, 1971).
A high glucose concentration in the camel could be associated with a small glucose space, or it may depend on an intricate control mechanism entirely different from that of advanced ruminants, or may be a direct consequence of anatomical differences in the forestomachs of the two species.

Data on plasma glucose concentrations, glucose entry rates, and recycling in various mammalian species and the chicken at different physiological and nutritional states are tabulated in Table 4. Regression of glucose entry rate (irreversible loss) on plasma glucose concentration (Fig. 2) demonstrates a highly positive relationship in different non-lactating, non-pregnant mammalian species which are in the fed state. This relationship supports earlier work, showing a positive correlation between plasma glucose concentration and glucose entry rate in the sheep (Bergman, 1964; Annison et al., 1967; Bergman et al., 1974). On the other hand, the values of 1.2 g/hr per kg B wt$^{0.75}$ and 200 mg/100 ml for entry rate and plasma glucose concentrations, respectively reported in the chicken by Belo et al. (1976) do not fit this curve. Perhaps the relationship in the avian species is different from that of mammals. Interestingly enough, values for pregnant, or lactating mammals (Bergman, 1963, 1964; Kronfeld and Raggi, 1964; Bergman and Hogue, 1967; Bergman et al., 1970; Leng, 1970; Evans, 1971; Bergman et al., 1974) also do not fit this regression line. Regression of glucose entry rate on plasma glucose concentration made (not presented) separately in lactating, or pregnant mammals also did not show a significant ($P>0.05$) relationship. Under these physiological states, glucose entry is elevated mainly as the result of an increase in food intake, and higher gluconeogenesis or glycogenolysis. Plasma glucose concentration, however, does not follow the increase in glucose entry rate due to the high demand of the foetus or mammary gland for glucose. In starved animals also no relationship was found.
Ketone body metabolism

In monogastric animals, ketone bodies (acetoacetate and 3-hydroxybutyrate) are produced in the liver from mobilization and oxidation of fatty acids. On the contrary, in ruminants, the rumen epithelium is the major site for ketone body synthesis (Pennington, 1952; Annison et al., 1957, 1963a; Hird and Weideman, 1964). In the fed state, the liver plays a minor role in this respect in ruminants (Leng and West, 1969). The main precursor of ketone bodies in the rumen epithelium is butyrate originating from carbohydrate fermentation in the rumen (Hungate et al., 1961). In addition to the synthesis of ketone bodies, butyrate is also oxidized in part to CO₂ in the rumen epithelium (Pennington, 1954; Goosen, 1976). The rumen epithelium of the camel is devoid of pappilae (Vallenas et al., 1971), and the camel lacks the third compartment (omasum) (Hansen and Schmidt-Nielsen, 1957) which is reported to produce some ketone bodies in ruminants (Pennington, 1952; Hird and Symons, 1961). It was considered likely that ketone body metabolism in the camel may have variation from that of other ruminants.

The activity of 3-hydroxybutyrate dehydrogenase (BHB-deH₂) (E.C. 1.1.1.30) is measured in the rumen epithelium and the liver of the camel and sheep. BHB-deH₂ is one of the key enzymes leading to ketone body formation. Plasma concentration of 3-hydroxybutyrate (BHB) and acetoacetate (AcAc), which are the main ketone bodies, are also measured in the fed and 96 hours fasted camels and sheep maintained under similar conditions. Hungate et al. (1959), and Williams (1963) reported that the rumen function in the camel yields the same products at rates and in proportions comparable to those in true ruminants. Therefore, the oxidation of butyrate to ketone bodies and CO₂ are studied in the rumen epithelium, liver, kidney, heart and lung of the camel, sheep and goat.
Experimental

Five camels (Camelus dromedarius), and five mature sheep were housed individually and fed ad libitum a mixed alfalfa hay and chopped barley straw diet. During the period of food deprivation, water was available free of choice. Ketone bodies were measured as described by Chandrasena et al. (1979b). The method of Chandrasena et al. (1979b) was utilized for determination of BHB-deH₂ activity in rumen epithelium and liver obtained from slaughtered camels and sheep.

Oxidation of butyrate to ketone bodies and CO₂ was done in the rumen epithelium, liver, kidney, heart and lung in camels, sheep and goats obtained from Shiraz city abattoir. The incubation was carried out under oxygen gas in an Erlenmeyer flask with a rubber stopper and removable central glass well. This well contained 0.25 ml hyamine-hydroxide, and a filter paper. The incubation medium contained 45 μmoles KCl, 6 μmoles EDTA, 15 μmoles MgCl₂, 150 μmoles Tris, 37.5 μmoles K₂HPO₄, 37.5 μmoles KH₂PO₄, 30 μmoles n-butyric acid, 1 Ci n-butyrate-1⁻¹⁴C, and 0.5 tissue slice in a total volume of 3 ml and at pH 7.1. The reaction mixture was incubated at 37°C for 1 hour. The reaction was terminated by injecting 2 ml of 10 percent perchloric acid (w/w). The reaction mixture was shaken for an extra two hours to trap the released CO₂. Control samples were utilized. The counting of ¹⁴CO₂ was carried out as described (Emmanuel et al., 1976). For determination of ketone bodies, the acidified reaction mixture was transferred and centrifuged. The supernatant fluid was neutralized and ketone bodies were measured as described previously (Chandrasena et al., 1979b).

Results and discussion

The levels of ketone bodies in the plasma of the sheep in the present studies (Table 5) are in agreement with the literature data on nonpregnant-nonalactating sheep
in the fed state (Leng and West, 1969; Bergman et al., 1963). Ruminants under normal dietary regimen have considerable quantities of ketone bodies of the order of 2-5 times higher than those of monogastrics (Annison et al., 1967; Bergman et al., 1968; Bates et al., 1968; Romsos et al., 1974; Emmanuel, 1976). The concentrations of BHB and AcAc in the sheep (Table 5) were 33 and 4 times higher than respective values for the camel maintained under the same conditions.

A linear relationship between the entry rates of ketone bodies and their respective plasma concentrations up to about 10 mg/100 ml has been reported for sheep (Bergman et al., 1963; Bergman and Kon, 1964; Leng and Annison, 1964; Leng, 1965; Annison et al., 1967). This correlation is true for urea (Fig. 1), glucose (Fig. 2), and lactic acid in ruminant and monogastric animals. It could be postulated then that the camel would have very low entry rates (utilization rates) of ketone bodies. The low ratio of BHB to AcAc resembles hepatic ketogenesis found in monogastrics (Tobin et al., 1972; Romsos et al., 1974, 1975; Emmanuel, 1976) in marked contrast to true ruminants (alimentary ketogenesis) in which this ratio is high.

The activity of BHB-deH₂ in the rumen epithelium (alimentary ketogenesis), and the liver (hepatic ketogenesis) of sheep were 66.0 and 13.3 μmoles/hr per g wet wt tissue, respectively, which supports directly the work of Koundakjian and Snoswell (1970), and indirectly the observations of Leng and West (1969). The rumen epithelium and the liver of the camel showed little activity of the enzyme comparable to that of the sheep (9 and 1.4 times less) suggesting very low production rates of ketone bodies by these tissues.

The results on low concentrations (and indirectly low entry rates) of ketone bodies in the camel can be explained by a) low activity of BHB-deH₂ in the rumen epithelium and the liver, b) lack of papillae in the rumen epithelium which greatly reduces the surface
area available for metabolic functions, and c) lack of omasum which produces some ketone bodies (Pennington, 1952; Hird and Symons, 1959).

The above observations raise interesting speculations on the metabolic fate of butyrate in the camel which is known to be produced in the rumen of the camel of the same order of true ruminants (Hungate et al., 1959; Williams, 1963). Metabolic studies by Pennington (1952), and Hird and Symons (1959) showed that the rumen epithelium, omasum and liver are the major sites for synthesis of ketone bodies from butyrate. In addition, Pennington (1954) reported that butyrate is also oxidized to CO₂ by rumen epithelium. Experiments were conducted here to study the oxidation of butyrate to ketone bodies and CO₂ by various tissues of the camel, sheep and goat.

Enzymes of ketogenesis catalysing the reactions leading from butyrate to ketone bodies in the rumen epithelium have been shown (Lahunta, 1965; Koundakjian and Snoswell, 1970; Baird et al., 1970; Bush and Milligan, 1971; Watson and Lindsay, 1972; Ash and Baird, 1973; Weeks, 1974 a,b; Chandrasena et al., 1979b; Emmanuel, Giesecke and Stangassinger, unpublished data). The operation of Krebs cycle in the rumen epithelium has been reported (Seto and Umez u, 1959; Annison et al., 1963a; Seto et al., 1970), thus enabling the oxidation of butyrate to CO₂.

Data on the conversion of butyrate to ketone bodies are presented in table 6. The rumen epithelium of the goat produced high quantities of ketone bodies which agrees with the work of Fell and Weeks (1975). The values in the sheep were about twice lower than in the goat, and are related to observations performed on cows (Goosen, 1976). Higher conversion rates in the rumen epithelium of the cattle and the lamb were found (Bush et al., 1970; Giesecke et al., 1979). On the other hand, the production rates in the rumen epithelium of adult sheep and cattle were 6.2 and 5.5 μmoles/hr per g wet
wt, respectively (Stangassinger et al., 1979). It appears then that the conversion of butyrate to ketone bodies in ruminants is influenced by factors including species, diet and developmental stage of the rumen epithelium. In addition, experimental conditions such as availability of oxygen in the incubation medium and pH (Pennington and Sutherland, 1956) may affect greatly the results. The production of ketone bodies in the camel was negligible (Table 6) which supports earlier observations (Chandrasena et al., 1979b). Ratios of BHβ to AcAc were 0.72, 1.10, and 1.32 for the camel, sheep and goat, respectively. Ketone body production in the liver was less than in the rumen epithelium, but followed the same pattern. The results on the kidney were comparable in three species tested.

Rumen epithelium and the liver of the goat oxidized more butyrate to CO₂ than that of the sheep (Table 6). Both tissues of the camel oxidized very little butyrate. On the other hand, the kidney of the camel oxidized more than that of other two species. The results of butyrate oxidation support earlier investigations, showing very little conversion of butyrate to CO₂ by various tissues including sheep liver (Leng and Annison, 1963), sheep rumen epithelium and omasum (Hird and Symons, 1959, 1961), and cow rumen epithelium (Goosen, 1976). Butyrate was not oxidized to ketone bodies, or to CO₂ to a great extent in the camel. It is possible that butyrate is metabolized by other tissues not tested in the present studies, or it can serve as a precursor for fat synthesis in the adipose tissue (mainly hump). Some butyrate was oxidized in the kidney providing energy for this organ which is known to be very active in this animal (Schmidt-Nielsen, 1964). In all species studied, the heart and lung converted little butyrate either to ketone bodies, or to CO₂.

Fatty acids in ruminants

Microbial function in the rumen leads to biohydrogenation and isomerization of plant fatty acids, and also to de
enovo synthesis of odd-numbered, and branched-chain fatty acids (Church, 1971). As the result, the depot fat of ruminants is little subject to dietary regimen as opposed to monogastrics. Fatty acid components from various related sources are shown in Table 7. Plant fats are characterized by containing high proportions of unsaturated acids (60-80 percent) (Keeney, 1970; Church, 1971). The rumen digesta, protozoa, and bacteria however contain mainly saturated acids (only 17-33 percent unsaturated acids). On the other hand, odd-numbered, and branched-chain fatty acids (4-8 percent) are found in their lipids (Keeney, 1970; Williams and Dinusson, 1973; Emmanuel, 1974). The subcutaneous fat in the sheep and steer contains about 50 percent unsaturated fatty acids; mainly oleic (18:1), little palmitoleic (16:1), and no linolenic (18:3). Both camel and deer fats are more saturated (60-70 percent; mainly palmitic and stearic acids) than those of the sheep and steer. Some branched-chain, and oddnumbered fatty acids (1-2 percent) are found in ruminant lipids. Ruminant milk fats are characterized by the presence of substantial amounts of short-chain, and medium-chain fatty acids resulting from de novo synthesis of simple metabolites (acetate, propionate, butyrate and 3-hydroxybutyrate) (Dimick et al., 1970). In general, the fats of ruminants are more saturated than those of monogastrics (Hilditch, 1956).

In conclusion, as compared to true ruminants, the camel shows differences in many metabolic processes. Further studies are required to understand various mechanisms involved in such processes. Work is in progress to study further biochemical aspects of ketone body, glucose and lipid metabolism in this species.
Table 1: Urea metabolism in camels, sheep, goats and calves

<table>
<thead>
<tr>
<th>Dietary crude protein content (%)</th>
<th>Camel</th>
<th>Camel</th>
<th>Camel</th>
<th>Sheep</th>
<th>Goat</th>
<th>Calf</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>9.6</td>
<td>13.1</td>
<td>9.6</td>
<td>9.6</td>
<td>9.6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average plasma urea-N (mg/100 ml)</th>
<th>8.89</th>
<th>14.09</th>
<th>21.07</th>
<th>13.20 (1.50)</th>
<th>12.36 (0.93)</th>
<th>13.07 (0.84)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea-N pool size (g)</td>
<td>29.72</td>
<td>32.34</td>
<td>58.80</td>
<td>3.16 (0.49)</td>
<td>2.40 (0.22)</td>
<td>6.11 (0.44)</td>
</tr>
<tr>
<td>Urea-N entry rate</td>
<td>0.65</td>
<td>0.78</td>
<td>1.23</td>
<td>0.83 (0.10)</td>
<td>0.86 (0.15)</td>
<td>1.03 (0.11)</td>
</tr>
<tr>
<td>Urinary urea-N excretion rate</td>
<td>0.10</td>
<td>0.20</td>
<td>0.68</td>
<td>0.42 (0.07)</td>
<td>0.47 (0.11)</td>
<td>0.54 (0.08)</td>
</tr>
<tr>
<td>Urea-N degradation rate</td>
<td>0.55</td>
<td>0.58</td>
<td>0.55</td>
<td>0.41 (0.05)</td>
<td>0.39 (0.05)</td>
<td>0.49 (0.04)</td>
</tr>
<tr>
<td>Urea-N degradation rate*</td>
<td>0.85</td>
<td>0.74</td>
<td>0.45</td>
<td>0.50 (0.05)</td>
<td>0.46 (0.04)</td>
<td>0.47 (0.02)</td>
</tr>
<tr>
<td>Urea-N entry rate*</td>
<td>1.45</td>
<td>0.83</td>
<td>0.54</td>
<td>0.43 (0.06)</td>
<td>0.37 (0.07)</td>
<td>0.46 (0.06)</td>
</tr>
<tr>
<td>Degraded urea-N</td>
<td></td>
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<tr>
<td>Dietary crude N intake</td>
<td></td>
<td></td>
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</tbody>
</table>

* Expressed as g/day per kg B wt 0.75.

The values in brackets are ± S.D. (n=4).

Nitrogen intake (g/day) = crude protein intake (g/day)/6.25.

Terms used are defined previously (Emmanuel et al., 1976).

Table 2: Plasma urea concentrations, urea entry, excretion, and degradation rates, and nitrogen intake in ruminants

<table>
<thead>
<tr>
<th>Species</th>
<th>Plasma urea (mg/100 ml)</th>
<th>UER^a</th>
<th>UEXR^b</th>
<th>UDR^c</th>
<th>UDR^c/ UER^a</th>
<th>N-intake</th>
<th>UDC^d</th>
<th>N-intake^d</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Camel</td>
<td>0.89</td>
<td>0.65</td>
<td>0.10</td>
<td>0.55</td>
<td>0.85</td>
<td>0.39</td>
<td>1.45</td>
<td></td>
<td>Emmanuel et al., 1976</td>
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<tr>
<td>14.09</td>
<td>0.78</td>
<td>0.20</td>
<td>0.58</td>
<td>0.74</td>
<td>0.70</td>
<td>0.82</td>
<td></td>
<td></td>
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<tr>
<td>21.07</td>
<td>1.23</td>
<td>0.68</td>
<td>0.55</td>
<td>0.45</td>
<td>1.03</td>
<td>0.54</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>12.37</td>
<td>0.86</td>
<td>0.47</td>
<td>0.39</td>
<td>0.45</td>
<td>1.09</td>
<td>0.37</td>
<td></td>
<td></td>
<td>Emmanuel &amp; Emady, 1978</td>
</tr>
<tr>
<td>13.07</td>
<td>1.03</td>
<td>0.55</td>
<td>0.48</td>
<td>0.47</td>
<td>1.06</td>
<td>0.44</td>
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<tr>
<td>13.21</td>
<td>0.81</td>
<td>0.42</td>
<td>0.41</td>
<td>0.49</td>
<td>0.96</td>
<td>0.44</td>
<td></td>
<td></td>
<td>Cosimano &amp; Leng, 1967</td>
</tr>
<tr>
<td>2.61</td>
<td>0.14</td>
<td>0.01</td>
<td>0.13</td>
<td>0.93</td>
<td>0.23</td>
<td>0.57</td>
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<tr>
<td>5.60</td>
<td>0.38</td>
<td>0.05</td>
<td>0.33</td>
<td>0.87</td>
<td>0.28</td>
<td>1.11</td>
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<tr>
<td>16.89</td>
<td>0.84</td>
<td>0.35</td>
<td>0.49</td>
<td>0.58</td>
<td>0.91</td>
<td>0.54</td>
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<tr>
<td>7.75</td>
<td>0.53</td>
<td>0.29</td>
<td>0.24</td>
<td>0.45</td>
<td>0.58</td>
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<td>0.23</td>
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<td></td>
<td>Ford &amp; Milligan, 1970</td>
</tr>
<tr>
<td>9.10</td>
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<td>0.27</td>
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<td>0.58</td>
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<td>0.34</td>
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<td>0.74</td>
<td>0.39</td>
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<td>1.57</td>
<td>0.25</td>
<td></td>
<td>Nolan &amp; Leng, 1972</td>
</tr>
<tr>
<td>26.18</td>
<td>1.45</td>
<td>0.95</td>
<td>0.50</td>
<td>0.34</td>
<td>1.71</td>
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<td>0.40</td>
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<td>Allen &amp; Miller, 1976</td>
</tr>
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<td>0.21</td>
<td>0.51</td>
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<td>0.52</td>
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<td></td>
<td>Robbins et al., 1974</td>
</tr>
<tr>
<td>Lamb</td>
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<td>1.11</td>
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<td>0.11</td>
<td>0.99</td>
<td>0.14</td>
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<tr>
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<td>0.61</td>
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<td>1.33</td>
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<td>0.67</td>
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</tr>
<tr>
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<td>0.55</td>
<td>1.57</td>
<td>0.74</td>
<td>2.86</td>
<td>0.55</td>
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<tr>
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<td>1.88</td>
<td>0.56</td>
<td>1.32</td>
<td>0.70</td>
<td>2.72</td>
<td>0.49</td>
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</tr>
<tr>
<td>26.83</td>
<td>2.62</td>
<td>1.10</td>
<td>1.52</td>
<td>0.58</td>
<td>3.27</td>
<td>0.46</td>
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</tr>
<tr>
<td>22.31</td>
<td>2.73</td>
<td>1.12</td>
<td>1.61</td>
<td>0.59</td>
<td>3.47</td>
<td>0.46</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ a = \text{Urea-N entry rate (g/day per kg B wt}^0.75]\]
\[ b = \text{Urineal urea-N excretion rate (g/day per kg B wt}^0.75]\]
\[ c = \text{Urea-N degradation rate (g/day per kg B wt}^0.75]\]
\[ d = \text{Nitrogen intake (g-N/day per kg B wt}^0.75]\]
Table 3: Glucose entry rate, and plasma glucose concentration in the camel and sheep in the fed and fasted states.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Plasma glucose concentration (mg/100 ml)</th>
<th>Glucose entry rate (g/hr per kg B wt(^{0.75}))</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camel</td>
<td>129.4</td>
<td>0.42</td>
<td>Fed</td>
</tr>
<tr>
<td>Camel</td>
<td>106.6</td>
<td>0.25</td>
<td>Fasted</td>
</tr>
<tr>
<td>Sheep</td>
<td>65.0</td>
<td>0.23</td>
<td>Fed</td>
</tr>
<tr>
<td>Sheep</td>
<td>56.4</td>
<td>0.14</td>
<td>Fasted</td>
</tr>
</tbody>
</table>

Table 4: Glucose kinetics in mammals and chicken.

<table>
<thead>
<tr>
<th>Species</th>
<th>Plasma glucose concentration (mg/100 ml)</th>
<th>Total(^{a})</th>
<th>Irreversible</th>
<th>Recycling(^{c})</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camel</td>
<td>129</td>
<td>-</td>
<td>0.42</td>
<td>-</td>
<td>Chandrasena et al., 1979a</td>
</tr>
<tr>
<td>Sheep</td>
<td>63</td>
<td>-</td>
<td>0.26</td>
<td>-</td>
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</tr>
<tr>
<td>Sheep</td>
<td>57</td>
<td>-</td>
<td>0.22</td>
<td>-</td>
<td>Bergman, 1963</td>
</tr>
<tr>
<td>Sheep</td>
<td>62</td>
<td>0.23</td>
<td>0.23</td>
<td>0.06</td>
<td>Bergman and Hogue, 1967</td>
</tr>
<tr>
<td>Sheep</td>
<td>68</td>
<td>0.29</td>
<td>0.29</td>
<td>-</td>
<td>Leng, 1970</td>
</tr>
<tr>
<td>Sheep</td>
<td>61</td>
<td>-</td>
<td>0.24</td>
<td>-</td>
<td>Judson and Leng, 1972</td>
</tr>
<tr>
<td>Sheep</td>
<td>59</td>
<td>-</td>
<td>0.24</td>
<td>-</td>
<td>Bergman et al., 1974</td>
</tr>
<tr>
<td>Deer</td>
<td>114</td>
<td>0.40</td>
<td>0.26</td>
<td>0.14</td>
<td>Luick and White, 1975</td>
</tr>
<tr>
<td>Deer</td>
<td>112</td>
<td>0.40</td>
<td>0.26</td>
<td>0.14</td>
<td>Luick et al., 1973</td>
</tr>
<tr>
<td>Deer</td>
<td>98</td>
<td>0.41</td>
<td>0.17</td>
<td>0.24</td>
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</tr>
<tr>
<td>Deer</td>
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<td>0.60</td>
<td>0.33</td>
<td>0.27</td>
<td>&quot;</td>
</tr>
<tr>
<td>Goat</td>
<td>-</td>
<td>-</td>
<td>0.30</td>
<td>-</td>
<td>Annison et al., 1968</td>
</tr>
<tr>
<td>Cow</td>
<td>58</td>
<td>-</td>
<td>0.59</td>
<td>-</td>
<td>Leng, 1970</td>
</tr>
<tr>
<td>Cow</td>
<td>62</td>
<td>-</td>
<td>0.57</td>
<td>-</td>
<td>&quot;</td>
</tr>
<tr>
<td>Cow</td>
<td>66</td>
<td>1.08</td>
<td>0.50</td>
<td>0.58</td>
<td>Herbein et al., 1978</td>
</tr>
<tr>
<td>Cow</td>
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<td>1.03</td>
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<td>0.61</td>
<td>&quot;</td>
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<tr>
<td>Horse</td>
<td>102</td>
<td>0.68</td>
<td>0.39</td>
<td>0.29</td>
<td>Evans, 1971</td>
</tr>
<tr>
<td>Pony</td>
<td>73</td>
<td>-</td>
<td>0.36</td>
<td>-</td>
<td>Argenzio and Hintz, 1972</td>
</tr>
<tr>
<td>Horse</td>
<td>79</td>
<td>-</td>
<td>0.25</td>
<td>-</td>
<td>&quot;</td>
</tr>
<tr>
<td>Horse</td>
<td>-</td>
<td>-</td>
<td>0.34</td>
<td>-</td>
<td>Anwer et al., 1975</td>
</tr>
<tr>
<td>Horse</td>
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<td>0.32</td>
<td>0.30</td>
<td>0.02</td>
<td>Anwer et al., 1976</td>
</tr>
<tr>
<td>Rabbit</td>
<td>141</td>
<td>0.30</td>
<td>0.21</td>
<td>0.09</td>
<td>Katz et al., 1974</td>
</tr>
<tr>
<td>Dog</td>
<td>121</td>
<td>-</td>
<td>0.42</td>
<td>-</td>
<td>Steele et al., 1956</td>
</tr>
</tbody>
</table>

Fasted

| Camel   | 107                                      | -             | 0.25         | -              | Chandrasena et al., 1979a |
| Sheep   | 56                                       | -             | 0.14         | -              | "          |
| Sheep   | 74                                       | -             | 0.17         | -              | "          |
| Sheep   | 52                                       | -             | 0.35         | -              | Kronfeld and Simensen, 1961 |
| Sheep   | 53                                       | -             | 0.19         | -              | "          |
| Sheep   | 56                                       | -             | 0.15         | -              | Bergman, 1963 |
| Sheep   | 54                                       | -             | 0.15         | -              | Bergman et al., 1974 |
| Goat    | -                                        | -             | 0.22         | -              | Annison et al., 1968 |
| Cow     | 48                                       | -             | 0.30         | -              | Leng, 1970 |
| Horse   | 81                                       | 0.57          | 0.19         | 0.38           | Evans, 1971 |
| Pony    | 66                                       | -             | 0.18         | -              | Argenzio and Hintz, 1972 |
| Pony    | 98                                       | 0.24          | 0.19         | 0.05           | Anwer et al., 1976 |
| Rabbit  | 140                                      | 0.32          | 0.24         | 0.08           | Dunn et al., 1976 |

Cont'd
Table 4 Cont'd: Glucose kinetics in mammals and chicken.

<table>
<thead>
<tr>
<th>Species</th>
<th>Plasma glucose concentration (mg/100 ml)</th>
<th>Total(^a) entry rate</th>
<th>Irreversible loss</th>
<th>Recycling(^c)</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>56</td>
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<td>0.55</td>
<td>-</td>
<td>Bergman and Hogue, 1967</td>
</tr>
<tr>
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<td>61</td>
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<td>0.50</td>
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<tr>
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<td>-</td>
<td>0.45</td>
<td>-</td>
<td>&quot;</td>
</tr>
<tr>
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<td>-</td>
<td>-</td>
<td>1.08</td>
<td>-</td>
<td>Leng, 1970</td>
</tr>
<tr>
<td>Goat</td>
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<td>-</td>
<td>0.81</td>
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<tr>
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<td>-</td>
<td>0.50</td>
<td>-</td>
<td>Leng, 1970</td>
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<tr>
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<td>74</td>
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<td>-</td>
<td>&quot;</td>
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<tr>
<td>Horse</td>
<td>93</td>
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<td>0.66</td>
<td>0.51</td>
<td>Evans, 1971</td>
</tr>
<tr>
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<td>-</td>
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<td>-</td>
<td>Kronfeld and Raggi, 1964</td>
</tr>
<tr>
<td>Pony</td>
<td>-</td>
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<td>0.94</td>
<td>-</td>
<td>Anwer et al., 1975</td>
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<table>
<thead>
<tr>
<th>Species</th>
<th>Lactating</th>
<th>Pregnant</th>
<th>Fed</th>
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<td>52</td>
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<td>Sheep</td>
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<td>0.32</td>
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<td>Sheep</td>
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<td>0.19</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Chicken</td>
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<td>1.22</td>
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<td>Chicken</td>
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<td>0.78</td>
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<tr>
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<td>218</td>
<td>0.92</td>
<td>0.53</td>
<td>0.39</td>
</tr>
</tbody>
</table>

\(^a\) Total entry rate = the rate of entry (mass per unit time) of all defined substances into the sampled compartment (g/hr per kg B wt\(^0.75\)).

\(^b\) Irreversible loss = the rate at which the defined substance (mass per unit time) leaves the sampled compartment never returns to that compartment (g/hr per kg B wt\(^0.75\)).

\(^c\) Recycling = the difference between total entry rate and irreversible loss (g/hr per kg B wt\(^0.75\)).
Table 5: Plasma concentrations of ketone bodies in the fed and fasted camels and sheep.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Fed</th>
<th>96 hr fasted</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BHB (mg/100 ml)</td>
<td>AcAc (mg/100 ml)</td>
<td>BHB (mg/100 ml)</td>
</tr>
<tr>
<td>Camel</td>
<td>0.089 (0.004)</td>
<td>0.148 (0.006)</td>
<td>0.61 (0.05)</td>
</tr>
<tr>
<td>Sheep</td>
<td>2.97 (0.29)</td>
<td>0.63 (0.07)</td>
<td>4.79 (0.20)</td>
</tr>
</tbody>
</table>

The values in brackets are ± S.E.M (n=5).

Table 6: Conversion (μ moles/hr per g wet wt tissue) of butyrate to ketone bodies and CO₂ by the rumen epithelium, liver and kidney of the camel, the sheep and the goat.

<table>
<thead>
<tr>
<th>Product</th>
<th>Epithelium</th>
<th>Liver</th>
<th>Kidney</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Camel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BHB</td>
<td>0.12 (6;0.01)</td>
<td>0.32 (10;0.04)</td>
<td>0.44 (9;0.13)</td>
</tr>
<tr>
<td>AcAc</td>
<td>0.17 (6;0.05)</td>
<td>1.23 (10;0.22)</td>
<td>1.11 (9;0.22)</td>
</tr>
<tr>
<td>BHB/ AcAc</td>
<td>0.72</td>
<td>0.26</td>
<td>0.40</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.04 (6;0.01)</td>
<td>0.43 (10;0.07)</td>
<td>4.16 (9;0.45)</td>
</tr>
<tr>
<td></td>
<td>Sheep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BHB</td>
<td>6.42 (13;0.72)</td>
<td>1.30 (13;0.33)</td>
<td>0.80 (13;0.33)</td>
</tr>
<tr>
<td>AcAc</td>
<td>5.85 (13;1.83)</td>
<td>1.53 (13;0.32)</td>
<td>0.74 (13;0.11)</td>
</tr>
<tr>
<td>BHB/ AcAc</td>
<td>1.10</td>
<td>0.85</td>
<td>1.08</td>
</tr>
<tr>
<td>CO₂</td>
<td>2.76 (13;0.50)</td>
<td>0.86 (13;0.09)</td>
<td>1.34 (13;0.23)</td>
</tr>
<tr>
<td></td>
<td>Goat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BHB</td>
<td>13.31 (6;2.95)</td>
<td>3.00 (6;0.74)</td>
<td>0.92 (6;0.25)</td>
</tr>
<tr>
<td>AcAc</td>
<td>10.08 (6;2.34)</td>
<td>2.86 (6;0.30)</td>
<td>0.86 (6;0.07)</td>
</tr>
<tr>
<td>BHB/ AcAc</td>
<td>1.32</td>
<td>1.05</td>
<td>1.07</td>
</tr>
<tr>
<td>CO₂</td>
<td>5.43 (6;1.25)</td>
<td>1.68 (6;0.32)</td>
<td>1.82 (6;0.40)</td>
</tr>
</tbody>
</table>

The values in brackets are number of observations, and ±SD, respectively. BHB and AcAc are 3-hydroxybutyrate and acetoacetate, respectively. The reaction mixture is described in the Experimental section.
Table 7: Percent fatty acid composition from different related sources.

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Dietarya</th>
<th>Mixedb</th>
<th>Rumenb</th>
<th>Mixedd</th>
<th>Sub-Ob</th>
<th>Sub-Qc</th>
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Symbols used are: 12:0 for a normal saturated acid with 12 carbon atoms; 14:0 br for a branched saturated acid with 14 carbon atoms, and 16:1 for a normal monoenoic acid with 18 carbon atoms.

Sub-Q = Subcutaneous.

* Includes also fatty acids with less carbon atoms.
Fig. 1: Regression of urea entry on plasma urea concentration in ruminants. The regression equation is: \[ Y = 0.1338 + 0.05307X \] (Sb = 0.00338; P = 0.001). References used are: camel (Emmanuel et al., 1976); goat (Emmanuel and Emady, 1978); calf (Emmanuel and Emady, 1978); sheep (Cosimano and Long, 1967; Ford and Milligan, 1970; Nolan and Leng, 1972; Allen and Miller, 1978; Emmanuel and Emady, 1978); deer (Robbins et al., 1974) and lamb (Allen and Miller, 1976).

Fig. 2: Regression of glucose entry on plasma glucose concentration in fed, non-pregnant, non-lactating mammals. The regression equation is: \[ Y = 0.16316 + 0.00151 \] (Sb = 0.00032, P = 0.001). References used are: camel (Chandrasena et al., 1979a); sheep (Kronfeld and Simesen, 1961; Annison and White, 1961; Annison et al., 1967; Bergman and Hogue, 1967; White et al., 1969; Bergman et al., 1970; Long, 1970; Judson and Leng, 1972; Bergman et al., 1974; Brockman et al., 1975; Chandrasena et al., 1979a); deer (Luick et al., 1973; Luick and White, 1975); dog (Steele et al., 1956; Steele et al., 1959; Issekutz and Allen, 1972; Issekutz et al., 1972); pony (Argenzio and Hintz, 1972; Anwer et al., 1976); horse (Evans, 1971); rat (Bergman, 1963; Katz et al., 1974), and man (Streja et al., 1977).
REFERENCES


Emmanuel, B. 1976 Effects of 1,3-butandiol and 1,2-porpanediol on growth, blood metabolites, and liver glycogen in broiler chickens. Poult. Sci. 55:2289-2294.


SECTION F

CAMEL DISEASES AND TOXICOLOGY
DROMEDARY PATHOLOGY

D. Richard

Summary

Disease is the most important factor in limiting camel production. Parasitisms are dominant, generally occurring in a chronic form entailing a drop in milk and meat yields and adversely affecting the calving rate.

The principal curative and prophylactic control measures are described, and it is concluded that the means are available to control all the main diseases of the dromedary.

Introduction

Relatively little is known of the pathology and breeding of camels. The remarkable heat regulation system and water metabolism have permitted its adaptation to environments in which water and vegetation are scarce (Gauthier-Pilters, 1961, 1969; Richard, 1975; Schmidt-Nielsen, 1956). Few technicians have had access to the inhospitable environment in which the herds are widely scattered.

A survey of the literature on camel production reveals the fact that data and precise descriptions relate mainly to dead animals; carcass yields and the lists of parasites are reported from established slaughterhouses, while biochemical studies and rinderpest experiments are conducted under laboratory conditions. Data concerning live animals are scarce because they are constantly on the move. There are clinical and bacteriological descriptions of infectious diseases in their acute form which are often contradictory.

Camel breeding and camel production provide a source
of income in desert areas in which these activities represent the only possible means of development. It is therefore important to acquire much more knowledge of all aspects of camel biology in order to increase productivity. Disease is a major impediment to improved output.

There is a high mortality rate in calves and young animals under 12 months of age. Parasitisms and infectious diseases reduce milk and meat yields in adults and may cause abortion. They entail weight loss and greatly limit the total output.

It must be emphasized that for the same intake of feed a sound and healthy animal will thrive better than one that is parasitized (Graber, 1966).

Pathology

There are no diseases that are specific to the dromedary. All the infections that have been reported are known to exist in other domestic animals. Symptoms of disease, however, are often missing or obscure (Leese, 1927; Curasson, 1947). There is truth in the reiterated statement that a sick dromedary moves about and suddenly lies down and dies. The uniqueness of the sick dromedary is defined by the statement "What gives dromedary pathology its characteristic features is less the animal itself than the environment in which it lives and the way it is bred and used" (Curasson, 1947). The influence of the environment and of the breeding techniques are evidenced by the rarity of widespread epizootics among dromedaries (compared to, say, rinderpest and foot-and-mouth disease in cattle) and by the generally low incidence of infectious diseases. The low density of the camel population in its traditional habitat areas and the long intervals between waterings mean that the close or frequent contacts necessary for the transmission of infection are avoided (Schmidt-Nielsen et al., 1956; Gauthier-Pilters, 1961, 1969). All the observations on epizootics have been made at watering points during
the dry season (Donatien, 1921; Donatien and Larrieu, 1922; Donatien and Boue, 1944). Furthermore the dromedary can be isolated from infection because the drinking requirement is not frequent as compared to cattle.

Under natural conditions the dromedary has few contacts with other animal species. The camel herder allows his animals to graze and browse in a radius of 50 km around the watering point while the cattle herder and the shepherd will not go beyond 20 km distant (Bremaud, 1969). Cattle, sheep, and goats will graze a surface area of 1 257 square km including the area immediately surrounding the watering point which is generally overgrazed. The dromedary will graze an area of 6 597 square km, or five times as much, where it will have few or no contacts with other animals.

Quantitively microbial disease is less severe in the dromedary than in other domestic animals. Camel pox is the major viral disease: outbreaks occur regularly among young animals with variable severity.

The part played by the dromedary in viral epizootics affecting cattle has often been debated. The low receptivity of the dromedary to rinderpest in field conditions has been recognized (Maurice et al., 1967; Bares, 1968; Richard, 1975). Following an experimental injection of rinderpest virus there is a small rise in temperature and an immunologic reaction (Singh and Ata, 1967; Provost et al., 1968; Taylor, 1968). The questions of dromedary receptivity to a modified virus and its role as a vector have still to be elucidated.

No foot-and-mouth disease antibodies were detected in serum samples from in-contact camels during an outbreak of FMD in cattle (Richard, 1975).

The dromedary does not appear to be susceptible to pleuropneumonia (Bares, 1968). Susceptibility to bacterial diseases in general has been confirmed in a few cases only which explains the lack of precision in cli-
nical descriptions and the difficulty of making a differential clinical diagnosis.

Anthrax (Cross, 1917; Curasson, 1947; Leach, 1961) and salmonellosis (Donatien and Boue, 1944; Olitzki and Ellenbogen, 1940; Zaki, 1956; Nawito et al., 1968; Ambwani and Jatkar, 1973; Cheyne et al., 1977) are the two acute infections which have been confirmed by bacteriological tests. The agents responsible for blackleg and pasteurellosis have never been isolated from dromedary samples.

Bacteriological proof that this animal is susceptible to blackquarter is still lacking, while for pasteurellosis some clinical and serological features hint at the presence of this disease (Pegram and Scott, 1976). In the light of existing knowledge Maurice et al. (1967) prefer to use the expression "pulmonary affections complex" or "respiratory disease complex" in which rickettsiosis PI3 virus infection and pasteurellosis are included.

The presence of brucellosis has been established by serological and bacteriological examination (Zaki, 1948; Viquier, 1953; Maurice et al., 1967; Bares, 1968; Kulshreshthta et al., 1974; Richard, 1975). It is difficult to diagnose the disease clinically because abortions from various causes are frequent.

Concerning chronic infectious diseases of bacterial origin, pyogenic diseases have long been recognized (Cross, 1917; Curasson, 1947; Leach, 1961). Corynebacteriosis, which is widespread, has been clearly identified (Esterabad et al., 1975; Domenech et al., 1977). Skin necrosis and suppurating wounds are also common (Cross, 1917; Curasson, 1947; Leach, 1961; Edelsten and Pegram, 1974; Richard, 1974; Domenech et al., 1977).

The dromedary plays an important role as a reservoir and carrier of numerous zoonoses, e.g. rickettsiosis, the existence of which has been confirmed serologically
though the clinical picture is unknown (Elyan and Dawood, 1954; Malek, 1959; El Nasri, 1962; Graber, 1966; Bares, 1968).

Sporadic cases of other diseases of the dromedary such as tuberculosis, tetanus and rabies have been reported, but the number of infectious diseases which occur in the camel is relatively small. Parasitic diseases are dominant.

Trypanosomiasis (T. evansi) is the most widespread disease of camel herds and causes heavy losses. It is present throughout the entire distribution area of the dromedary in Africa and Asia, with variable infection rates (Droandi, 1936; Curasson, 1947; Gruvel and Balis, 1965; Awkati and Al-Khatib, 1972; Richard, 1975; Luckins et al., 1979). The disease usually assumes the chronic form. Other protozooses are of minor importance (Graber, 1966; Gill, 1976; Ginawi, 1977).

Helminthiases are widespread with infestation rates thought to be around 90 percent. Recent surveys have indicated the effect of the disease on production (Steward, 1950; Malek, 1959; Perry, 1961; Gruvel and Balis, 1965; Queval et al., 1967; Ramachandran Iyer et al., 1968; Graber, 1969; Altaif, 1974; Daynes and Richard, 1974; Burgemeister et al., 1975; Blaizot, 1976; Troncy and Oumate, 1976).

Myiasis of the nasal cavity due to the larvae of Cephalopsis titillator is frequent but is often inconspicuous. This is the commonest external parasite. In Chad and Ethiopia all dromedaries are infested. The larvae can cause brain compression and nervous disorders which may result in death (Graber and Gruvel, 1964; Daynes and Richard, 1974).

Mange is common and is economically important.

Tick infestation is widespread and can be severe.
Little is known of nutritional deficiency disease which is believed to be of common occurrence. It takes many clinical or subclinical forms (Durand, 1958; Durand and Kchouk, 1958).

The environment exercises an influence on all disease conditions. In good pasture areas the dromedary is more resistant to infection, but if the region is well-watered there will be a high insect population and trypanosomiasis and the helminthiases will be widespread. On low productivity pastures, the dromedary is more vulnerable to mange and digestive troubles. According to Peck (1938 a; 1938 b; 1939) pyogenic conditions are more common where there is salt deficiency.

Husbandry is also important. In the U.S.S.R., where farm camels are maintained in close proximity to each other, the brucellosis infection rate is high (Pal'Gov and Zhalobovski, 1964). In Chad, 33 percent of the dromedary population showed a positive serological reaction (Blaizot, 1976). In Ethiopia, 51 percent were positive (Richard, 1975).

Paratuberculosis has also been described in U.S.S.R. (Strogov, 1957). This disease has never been reported as occurring under extensive conditions.

There is a relationship between certain disease conditions; for example, trypanosomiasis and massive helminthiasis pave the way for pulmonary affections (Ferry, 1961; Gruvel and Balis, 1965).

Production is adversely affected by

(a) high mortality, which means a low numerical productivity rate and a low, nil or negative herd growth;

(b) abortions which entail a low fertility rate with the same effects as mortality; and
(c) anorexia, tiredness and emaciation which lead to low milk and meat yield and infertility and may end in death.

An illness of brief duration can affect animal production for a long period. A female camel with a fever crisis of trypanosomiasis lasting for a few days will not regain the milk production that it had before. Lactation will resume with a lower yield.

Age groups are not necessarily susceptible to the same diseases: e.g. camel pox affects calves under 2 years of age while corynebacteriosis appears in the 3 to 4 year old group.

Most camel diseases are insidious in character and become chronic entailing a drop in meat and milk yields.

Treatment

Therapeutic treatment is not widely applied and relatively few drugs have been administered to camels. Curasson (1947) states that the camel can be treated with the same therapeutics as other large animals. However, it is necessary to be cautious when administering new medicaments and those whose effects have not been studied in the camel. Leach (1961) pointed out the toxicity of barenil (N.D.) for the camel and Graber (1969) reported the toxicity of tetramisole for this animal.

Graber, in his study on thiabendazole (1966), showed that it was a good anthelmintic treatment. Treated camels have a weight gain of 6.9 percent compared with the control group in the same pasture conditions. In his account of this experiment the author reports that camel herders observed an important regression of scabies in many animals.

A routine treatment of trypanosomiasis should be
established. In the absence of general prophylaxis, camel owners must be encouraged to have their animals treated when they move into a fly infested area.

The issue of drugs must be carefully controlled. Pregnant and lactating females should be the first groups to be treated.

Anthelmintic treatment of young animals should become an established routine. Administration of the drugs will give the best results when the infestation is at its lowest, i.e. during the dry season.

The treatment of mange, and vaccination against camel pox, anthrax and pyogenic diseases should all become routine. For pyogenic diseases, a vaccine prepared from strains of Corynebacterium pseudotuberculosis and Streptococcus isolated from camels is required.

The treatments mentioned above are not expensive: their cost will be met from the profits accruing from improved productivity.

The means and the knowledge are available to control all the main diseases of the dromedary. Research must be undertaken to extend the scope of the agents used in the control of parasitic diseases, particularly because the dromedary is idiosyncratic in its reaction to certain drugs.

REFERENCES AND BIBLIOGRAPHY


Awkati, A.J., and Al-Khatib, G.M., 1972. Trypanosomia-


Droandi, I. 1936 Il cammello; storia naturale, anatomia, fisiologia, zootechnica, patologia. Firenze, Instituto Agricolo Coloniale Italiano, 24 c, 856 pages. ill.


Durand, M., and Kchouk, M., 1958. Le krafft, une ostéo-


Graber, M. 1966 Etude dans certaines conditions de l'action antiparasitaire du Thia-bendazole sur divers Helminthes


A NOTE ON DISEASES OF CAMELS IN SAUDI ARABIA

I. Eldisougi Mustafa

Introduction

The camel thrives well in the Arabian peninsula and is considered to be the most adaptable animal for hot desert conditions. It has received special attention since prehistoric times and, although convincing evidence is lacking, it may well have been first domesticated in Saudi Arabia where it supported and sustained ancient civilizations which depended on camel caravans for transport and contacts.

There are several distinct types, all being the one-humped dromedary. They are maintained for meat, milk, hair and hides, as racing animals and to a declining degree as beasts of burden.

The population has declined in the present century and is currently estimated at approximately 162,000 (FAO, 1982).

Types

There is no clear distinction between the camels which are widely scattered throughout the desert and range-lands and those which graze and browse in the mountains along the Red Sea. In general desert camels, particularly in the north, are larger and bigger boned than those of the western highlands. The latter are mostly short, stout and dark brown or black in colour with a relatively thick coat. The plains camels are mostly white or fawn-coloured. Some are dark brown and a few are black in colour.

The best bred and finest camels in Saudi Arabia are those of Oman in the south-east of Arabia. They are referred to as Umaniyah. Arabic literature is rich
in synonyms given to the camel referring to the different stages of growth and the physical characteristics. The species and herds of camels are spoken of as "Al-ibil".

The common word for an individual camel is Ba‘īr. The male camel is Djamal, and the female Naga. An uncastrated male kept for breeding is Fahal, while racing camels are known as Higin. In poetry, Mahriyah refers to the fast, light riding animal while Bukht signifies a fine beast of burden.

The use of motorised transport has supplanted the camel caravans. On the other hand, the sport of Higin racing is increasing.

Camels are better milking animals than the foreign breeds of cattle which have been imported in considerable numbers in recent years and camel milking is being strongly encouraged. The milking camels are less susceptible than cattle to endemic diseases and are more tolerant to heat and the sparse, rough pastures of the desert and rangelands.

Major ailments

The main camel ailments encountered in Saudi Arabia are mange, pneumonia, pleurisy, hydatidosis and tick infestation.

1. Sarcoptic mange
This skin disease has been known since pre-Islamic times and is referred to in early literature as djarab or urr. It was the custom then to cauterize healthy animals in order to cure others afflicted with mange. The condition is still a considerable nuisance for camels and also for the Bedouin who are directly associated with them.
2. Pneumonia, pleurisy and pericarditis
A pneumonic complex known locally as Nahaz, seems to be of seasonal occurrence.

Collection of specimens from the abattoir has revealed a diversity of intrinsic and extrinsic aetiological factors. Apart from lung abscesses due to corynebacterium, the lesions consist of swelling, congestion and discoulouration and firmness of lobules. In some cases the lobules are separated by sero-fibrinous material and further complicated by pericarditis, pleurisy and excessive adhesion.

3. Hydatidosis
The disease is endemic throughout the region; the pathological and economical magnitude of the problem is understood by veterinarians who see severely affected cases. A great deal of infected meat is condemned in the abattoir. A very large number of cysts may be harboured in a single lung. The predilection sites are mainly the lungs, liver and spleen. The problem is serious as stray and domesticated dogs have access to dead animals and discarded offals.

4. Ticks
These are considered as a major veterinary problem especially where animals congregate for watering, marketing or slaughter. The species of ticks involved are mainly Amblyoma and the desert-acclimatized Hyalomma. They infest soft parts of the skin and attach themselves under the dock of the tail, in the perineum and around the ears and eyes. Adults, larvae and nymphs can be lodged deeply in the ears, causing severe irritation and discomfort, in response to which camels may rub against any hard object producing bleeding, sores and occasionally conjunctivitis.

Control measures are immensely difficult due to the spread of camels in the desert and the inefficiency of proper dusting or spraying by the owners. Adequate super-
vision and regular visits by veterinarians and veterinary assistants are necessary to control.

Other ailments

Camels are subject to many other parasitic, viral and bacterial diseases. However, these are of relatively low incidence and good results are expected to follow increasing veterinary attention and the establishment in Hofuf of a veterinary college and a training centre for veterinary assistants.

1. Parasitic diseases
Myiasis and camel bots are of some concern. Camel bots are seen seasonally in the nasopharynx while myiasis occurs after clipping or branding and following traumatic wounds.

Cases of fascioliasis in the camel are occasionally encountered in the abattoir.

F. gigantica and F. hepatica have recently been incriminated as the cause of the condition in the Eastern Province, Saudi Arabia (Magzoub and Kasim, 1978).

Schistosomiasis occurs in the southern and western highlands. The parasite can be collected from the mesenteric veins. Symptoms are seldom seen in infested animals.

Toxoplasmosis, sarcosporidiosis and cysticercosis are common in specimens collected from the slaughter house.

Trypanosomiasis is of sporadic incidence and is diagnosed by smears. Further investigations and a thorough disease survey are required.

Other internal parasites are occasionally collected from slaughtered camels in the abattoir, e.g. species of the genera Haemonchus and Trichostrongylus.
2. Viral diseases
Sporadic outbreaks of rinderpest and foot-and-mouth disease occur. Camels in the vicinity were not involved when three years ago an outbreak of rinderpest occurred in a dairy farm belonging to the College of Agriculture, University of Riyadh. Such reduced susceptibility to natural infection requires investigation.

Camel pox appears in a benign form, usually affecting young camels only. They show typical lesions in the form of papules, vesicles, pustules and crusts which are often localized in the lips, head and soft parts of the skin.

It is noteworthy that Bedouins occasionally report cases of crazed, violent and aggressive camels that can infect others. This could be rabies, but unfortunately the cases are beyond reach and are always reported when it is too late for any action by the veterinary service. There are many stray and feral dogs.

3. Bacterial diseases
Veterinarians have encountered sporadic outbreaks of acute and peracute anthrax. Affected animals were said to have shown oedematous swelling of the throat, head and neck.

Pulmonary tuberculosis is occasionally observed in camel carcases. Whether affected animals are indigenous or imported for slaughter remains to be verified.

Paratuberculosis and brucellosis have both been reported and a disease survey is required.

Other minor lesions in the camel are localized actinomycotic granulomas and cold abscesses mostly at the base of the neck. As in Sudan this is referred to in Arabic as Anaba.
4. Minor traumata

The introduction of motor transport minimized the role of the camel as a beast of burden; hence the reduction of skin lesions and traumas due to bad saddling, harnesses and rough loads. Nevertheless, camels grazing in the western highlands are prone to different types of traumata and fractures.

REFERENCES


A NOTE ON TRYPANOSOMIASIS IN SUDAN CAMELS

M.M. Mahmoud and M.O. Osman

Introduction

Camels in Sudan have always been known to suffer from trypanosomiasis due to Trypanosoma evansi which has been regarded as the most important of the camel diseases and has, over many centuries, claimed the lives of an incalculable number of camels. T. evansi was identified as the causal agent of the disease in Sudan about 1905 (Oliver, 1907), mechanically transmitted by tabanids and other blood-sucking insects. The disease is vernacularly known as Gufar, is well recognized and much dreaded by native camel owners. Prior to the availability of Naganol (Bayer 205), the disease went unchallenged resulting in the death of almost 90 percent of trypanosome-infected camels (Knowles, 1924).

The disease has consistently been reported over the years from camel raising areas. Its distribution is closely associated to that of tabanids and the intensity of outbreaks is directly related to the seasonal increase in fly numbers. There are, of course, trypanosomiasis free areas which are ecologically unsuited to tabanids, just as there are trypanosomiasis areas where camels cannot exist. In the latter areas camels usually succumb from trypanosomiasis due to other trypanosome species which are transmitted by the tsetse fly. Camel trypanosomiasis due to T. evansi can be prevalent between 10° - 15° N. West of the Nile and 12° - 18° N. East of it, taking the seasonal migration of camels and the consequent extension of trypanosomiasis into account (Karib, 1961).

Aetiology

Camel trypanosomiasis is mainly caused by T. evansi. Exhaustive reviews on the trypanosome have been given
by Hoare (1972) and Mahmoud and Gray (1980). It is considered as a subspecies of the Brucel-group trypanosomes which has been adapted over centuries to survival outside tsetse country and consequently has become unable to survive in and to be transmitted by the tsetse fly. *Trypanosoma congolense*, *T. brucei* and *T. vivax* have also been identified from camels in Sudan (Bennett, 1927) but their role is insignificant.

Epidemiology and transmission

Natural infections occur in camels as well as in other domestic stock, including horses, donkeys, mules and dogs, and in wild animals. Donkeys, cattle, sheep and goats might act as reservoir hosts (Mahmoud and Gray, 1980). Goats have been shown to harbour *T. evansi* infection for more than a year (Malik and Mahmoud, 1978). Although camels are usually maintained without close association with other animals, and do not often share the same husbandry conditions as cattle, the existence of carrier animals such as sheep and goats in the vicinity of susceptible camels makes transmission by tabanids possible. No wild animal has been identified as reservoir to *T. evansi* in Sudan although such animals have been incriminated elsewhere (Mahmoud and Gray, 1980).

Surveys of tabanids (Yagi and Razig, 1972 a, b, and 1975; Razig and Yagi, 1975) have shown that there is a definite correlation between the seasonal outbreaks of *T. evansi* infections and the increase in numbers of tabanids during the tropical rains in Sudan (June - October). Tabanids of the species *T. taeniola*, *Atylotus agrestis*, *A. fuscipes*, *T. biguttatus*, *Ancala latipes* and *Philoliche magrettii* have been identified at various times during the year and this explains the sporadic occurrence of the disease throughout the year with peak outbreaks during the rainy season.
Clinical manifestations

The disease is manifested by elevation of body temperature associated with presence of trypanosomes in the peripheral blood. Infected camels show progressive anaemia, loss of condition, weakness and often rapid death. Milder cases develop relapsing parasitaemia with or without pyrexia. Some camels develop oedema in their dependant parts. Some develop a characteristic sweet smell, readily identifiable by native camel owners. Some may harbour trypanosomes for 2 - 3 years, constituting reservoirs of infection for susceptible camels and hosts. Camels kept in restricted areas especially those under Government service, or kept for transport, draught and the expression of oil from oil-seeds milled in high rainfall areas, suffer more heavily from trypanosomiasis than those kept in open country by nomads, who are sufficiently mobile to avoid areas of high fly density.

Diagnosis

Demonstration of *T. evansi* in a camel blood smear is conclusive evidence of infection but 80 percent of positives can be missed in wet mounts (Bennett, 1933) and may be reported as false negatives, hence the continuing efforts directed toward improvement of diagnostic efficiency. Wet mounts coupled with the Mercuric Chloride Test have been standard methods of diagnosis since the official adoption of the latter (Bennett, 1933). More recently it has been shown that both methods are inadequate and diagnosis should be improved by the adoption of other methods in addition to the blood smear method. These are Immunofluorescence (IFAT) and Enzyme-Linked Immunosorbent Assay (ELISA) (Luckins et al., 1979). Even the Formol-Gel Test (Knowles, 1924) has been shown to be superior to the Mercuric Chloride Test (Luckins et al., 1979) and its revival as a diagnostic tool should be contemplated (Pegram and Scott, 1976).
Control

Prior to 1925 all camels found infected were destroyed owing to the lack of effective trypanocides. However, in 1925, the drug known as Naganol or Bayer 205 became available. When administered to government owned camels, a dramatic cure resulted and trypanosomiasis ceased to be a menace. Gradually its use spread to native owned camels. Chemotherapy has always been restricted to clinically confirmed cases and proven outbreaks. Trypanocides have been closely guarded by Government legislation and control. For a time most populations of *T. evansi* in Sudan were fully susceptible to Naganol (Antrypol) at the maximum dose of 10 g/camel. Most cases are still curable with this dosage. Where there is no response to Naganol, Antrycide methyl sulphate at 2 g/camel is given. Recently a strain of *T. evansi* isolated from a natural camel infection was found to be resistant to both Antry-pol and Antrycide methyl sulphate.

A review of the chemotherapeutics of *T. evansi* infections has been presented by Mahmoud and Gray (1980). Berenil has been found to be toxic to camels at levels curative to similar infections in other hosts (Leach, 1961). Studies are in hand to investigate the nature of this toxicity, and to determine whether it is possible to use Berenil to control resistant strains of *T. evansi*.

Isometamidium chloride (Samorin) has been found to give inconsistent results (Balis and Richard, 1977). It can be said, however, that camel trypanosomiasis can be reasonably well controlled by the available trypano-cides.

There is no efficient method of controlling tabanids due to their ubiquity and the inaccessibility of their development stages. There is no vaccine because problems of antigenic variation remain to be solved.
Discussion

The camel is emerging as a very valuable animal. In absolute terms camels constitute a considerable part of the total livestock resources of Sudan (Wilson, 1978). Sudan has one of the largest camel populations in the world (about 2.5 million), equivalent to over 15 percent of the world camel population (FAO, 1982).

For many centuries camels have been used as pack animals, for riding and transport, and to maintain security. They often provide the power to operate mills expressing oil from oil-seeds, or to draw water from deep bore wells. It is interesting to contemplate that the camel, as the animal least changed by domestication is perhaps the best adapted of all animals to its environment (Gillespie, 1966). The value of the camel is increasing every year due to the rising demand for it as a meat animal in Libya and Egypt, and as a racing animal in the Gulf States and Saudi Arabia. More cattle owners are turning to raising camels due to increasing desertification, and much more attention is being given to the camel as a milk producer. It seems that camel populations are bound to increase.

Recently, the usefulness of serodiagnosis of camel trypanosomiasis (Luckins et al., 1979), serum immunoglobulin levels (Boid et al., 1980 a) and serum enzyme changes during infection (Boid et al., 1980 b) have been studied. *T. evansi* has been successfully grown in vitro in the presence of Glossina morsitans explants (Mahmoud and Cunningham, 1979).

However, trypanosomiasis continues to exist while the research and manufacture of trypanocides is waning due to lack of interest on the part of drug manufacturers in producing this category of drugs because their manufacture is not considered to be economically feasible. Antrycide, for example, has ceased to be produced, possibly forever. Research must continue into alternative ways of control, the mapping of drug resistance and
chemotherapeutic agents. Control programs must adopt new methods of diagnosis and should involve other animals associated with camels if foci of infection are to be eliminated.

REFERENCES


Oliver, A. 1907 Sudan Veterinary Department Annual Report 1907, p. 841.


THE CURRENT STATE OF CHEMOTHERAPY OF T. EVANSI INFECTION IN CAMELS

D. Schillinger and D. Rottcher

Introduction

The main strategies in combating trypanosome infections of domestic animals are vector control, vaccination, breeding of immunotolerant animals, chemotherapy and chemoprophylaxis. There are, however, more obstacles for the implementation of these strategies in T. evansi infections (surra) in camels than are usually found with other domestic animals such as cattle.

Vector control, which is essentially limited to the use of insecticides in tsetse infested areas and the breeding of sterile males, is ineffective due to the transmission modus of surra which is independent of tsetse flies. Control of the transmitting biting flies (i.e. tabanids), which could be carried out in the same manner, is not feasible with nomadic camel husbandry.

Fortunately the camel seems to have acquired a certain amount of natural resistance in the course of its evolutionary development since the Pliocene epoch. In this respect camels can be classified between wild animals and selectively bred domesticated ruminants; thus it may be presumed that, as with cattle, there are differently developed resistances between the various breeding lines. It is not known if any breeding has been done to aim at the selection of this disposition, although it could well be imagined because of the excellence of the observation of African and Arab camel herders.

Vaccination to increase the defence mechanism of the host against trypanosome infections is one of the main aims of trypanosomiasis research. The development of an efficient vaccine is complicated by the ability of the trypanosomes to change their antigen structure.
There are, however, reports of encouraging results of vaccination experiments with *T. evansi* in laboratory rodents (Gill, 1965; Ryu, 1975; Hertkorn, 1980; Bremer, 1982). It can be concluded that the classical strategy of chemotherapy and chemoprophylaxis in camels is still of major importance, more so than for other domesticated species. Unfortunately most of the few commercially available drugs are not suitable for chemotherapy of surra, partly because of their low trypanocidal activity against *T. evansi*; there is also a particular species toxicity for camels which is characteristic of some compounds.

In 1974 the drug Antrycide (ICI) (Imperial Chemical Industries Ltd. (ICI) became unavailable because ICI stopped its production. This resulted in a critical situation as all trypanosomiasis treatment in camels had again to rely on only one drug, Naganol (Bayer), as in the beginning of chemotherapy.

Therapy with naphthalene derivates and quinapyramine

As early as 1925 naphthalene derivatives were marketed as Naganol by Bayer, which is also known as Antrypol (ICI), and Suramin (S.P.E.C.I.A.). The recommended application is by intravenous injection. A paravenous injection frequently leads to thrombophlebitis. The standard dosage for the adult camel is 5 g Naganol (10-12 mg/kg), dissolved in 50 ml sterile water. After more than 50 years of usage it is not astonishing that the effectiveness of Naganol is increasingly diminished by varying degrees of resistance. As early as 1961 Leach reported relapses after Naganol treatment. But at that time the use of Antrycide in cases of Naganol resistance was possible. When Antrycide (quinapyramine sulphate) was commercialized in 1950 good results were reported when injected subcutaneously at a dosage of 4.4 mg/kg body weight, 2 g being sufficient for an adult camel. Although it cost three times as much as Naganol,
Antrycide$^R$ was accepted as the trypanocide of choice for the curative treatment of surra. It is also effective against *T. congolense*.

Antrycide$^R$ Pro-Salt, containing a mixture of three parts quinapyramine sulphate and two parts of the almost insoluble quinapyramine chloride, was available for prophylactic treatment. This compound was distinguished by its simple subcutaneous application, low toxicity and prolonged prophylactic effect of up to 5 months. Gill and Malhotra (1963; 1971) demonstrated in mice and ponies that the period of prophylactic cover can further be extended when Antrycide$^R$ is administered in the form of the Antrycide$^R$-Suramin$^R$ Complex.

Therapy with other commercially available trypanocides (arsenical compounds, diamidines and phenanthridine derivatives)

Attempts have been made to widen the drug spectrum in camel therapy by the use of other trypanocidal compounds such as the arsenical compounds. These were first used in the treatment of human trypanosomiasis for which they are still indispensable. The use of arsenicals in the treatment of surra in the U.S.S.R. has been described by Ilovaisky and Zeiss (1924), and Zeiss (1937); they were discontinued when Naganol$^R$ became available. Trypanocidal activity of arsenical compounds for *T. evansi* is again described by Gill (1973).

The authors have recently carried out sensitivity tests of East African *T. evansi* isolates from camels in mice and have found that the arsenical compound Melarsoprol (Arsobal$^R$, S.P.E.C.I.A.), is curative at well below the recommended dosage for human trypanosomiasis and is also effective with Naganol$^R$- and Antrycide$^R$ resistant *T. evansi* strains. Subsequent usage of Arsobal$^R$ in clinical trials in camels with one application of 3.5 mg/kg body weight have been sufficiently encouraging to warrant continuing use. The curative effect of
Arsobal against *T. evansi* is not surprising when one considers the similarity of this trypanosome species to the *Brucel* group (Hoare, 1956), for which arsénicals have been successfully employed over many years.

One of the diaminidines, Diminacene aceturate (Berenil<sup>R</sup>, Hoechst), successful in cattle trypanosomiasis, has been tried against *T. evansi* infections. Harant (1978), experimenting with *T. evansi* infected mice, found that the curative dosage was as high as 15 mg/kg. Due to its specific species toxicity, however, Berenil<sup>R</sup> must not be used in camels. Although well tolerated by cattle, reports of deaths of camels are recorded after treatment with only 3.5 mg/kg and 7 mg/kg Berenil<sup>R</sup> (Leaf, 1961; Fazil, 1977). Homeida et al. (1981) treated two camels on 2 successive days with 10 mg/kg body weight. One camel died on the 8th day after treatment, the other was killed after the same period. One single application of 40 mg/kg body weight caused death within 4 hours. The clinical signs of Berenil<sup>R</sup> toxicity were salivation, frequent urination and defaecation, convulsions, sweating, recumbency and regurgitation. Post mortem findings showed haemorrhages in the heart, liver, kidney, urinary bladder and brain. Histopathological and histochemical examination of liver and kidney confirmed that these organic systems were damaged.

Sensitivity tests with phenanthridines in *T. evansi* infected rats (the trypanosome was isolated from a water buffalo) proved most of this class of chemicals to be ineffective (Gill, 1973). Gitatha (1980) conducted sensitivity tests in mice with *T. evansi* isolates from camels of East Africa and found that the phenanthridines, homidium bromide (Ethidium<sup>R</sup>, Boots Company Ltd.), homidium chloride (Novidium<sup>R</sup>, May and Baker), and isometamidium chloride (Samorin<sup>R</sup>, May and Baker) in different dosages would suppress parasitaemia only temporarily.

Balas and Richard (1977) also reported only limited activity of isometamidium against surra in camels. In
their experiments, where Samorin\textsuperscript{R} was given to camels in dosages of 0.5 - 1 mg/kg body weight intramuscularly and intravenously, the parasitaemia was suppressed for only 2-3 weeks. This period of curative effect is confirmed by Raghavan and Khan (1970), in \textit{T. evansi} infected cattle in India. Petrovskij (1974), on the contrary, found that the intramuscular application of 1 mg/kg body weight Samorin\textsuperscript{R} had a very good curative effect in 10 naturally infected camels in the Soviet Union. During his observation period of 2 months all camels remained parasite free.

New attempts to improve surra chemotherapy

The treatment of surra by application of isometamidium chloride (Samorin\textsuperscript{R}, May and Baker) is limited due to its low trypanocidal activity against \textit{T. evansi} infections and the local toxicity at high dosages. This is particularly obvious in camels. Painful abscesses and cyst formation at the injection site persist for months. Reduced well-being of the treated camels is common and irreversible tissue necrosis can develop. A series of experiments was carried out to eliminate these undesirable factors.

James (1978) combined isometamidium with dextran sulphate. Using this complex he noted ten times less local toxicity in mice. Aliu and Sannusi (1979) also reported that Zebu cattle treated subcutaneously with isometamidium-dextran showed no severe skin reaction.

Our experiments with Samorin\textsuperscript{R}-dextran complex also confirm a reduction of toxicity for the camel as compared with the application of Samorin\textsuperscript{R} alone. A mixture of equal parts of 4 percent dextran sulphate and 4 percent isometamidium solution given subcutaneously at 0.5 mg/kg body weight reduced the incidence of local symptoms by about half. In order to avoid the disadvantages of intramuscular treatment the intravenous administration of Samorin\textsuperscript{R} was attempted in cattle, goats and
horses (Bouchard and Dick, 1962; Finelle and Lacotte, 1963; Toure, 1973) and also with camels (Desrotour et al., 1974; Balis, 1977; Balis and Richard, 1977). This method of application is accompanied in all animal species by severe systemic toxicity which, depending on the dosage, can range from slight clinical symptoms to death by shock within a few minutes. In the present experiments it was found that in doses of up to 1 mg/kg body weight camels tolerate Samorin \textsuperscript{R} intravenously. At this dosage they show the following clinical symptoms: salivation, lachrimation, muscle tremors, altered heart rate, and frequent urination and defecation. After 15-30 minutes increased intestinal movement leads to diarrhoea lasting for approximately 4-6 hours. At 1.5 mg/kg temporary paralysis occurs (Schillinger et al., 1982). 2 mg/kg causes severe shock conditions (Balis and Richard, 1977).

With this knowledge of the systemic toxicity and the maximum tolerated dosage of intravenously injected Samorin \textsuperscript{R}, more than 200 intravenous Samorin \textsuperscript{R} injections were carried out in camel herds in the north of Kenya which had shown complete Naganol \textsuperscript{R} resistance in various treatment attempts and in mouse sensitivity tests. The dosages ranged from 0.25 mg/kg to 1 mg/kg in 0.5-1 percent solution. No serious side effects were noted. Camels at all stages of pregnancy were treated but no cases of loss of performance or of abortion were observed. All calves born after treatment were healthy. Whether due to re-infection or to relapse, nine months after the experiment was initiated, approximately one-third of the inoculated animals again showed parasitaemia. Whatever the final evaluation of this field trial, overall herd health shows marked improvement.

Results of therapy with new test compounds

Non-commercial substances with known trypanocidal activity from various sources have also been tested. One of these, Erlangen diamidine 150/49 (information kindly submitted by Prof. O. Dann, Erlangen, West Germany)
was consistently curative for mice infected with various T. evansi strains. However, in camels, the minimal curative dosage of 5 mg/kg body weight was found to be toxic. Symptoms were identical with the above described Berenil toxicity.

Another experimental substance, quinapyramine isethionate (kindly supplied from May and Baker), a quinoline salt chemically closely related to Antrycide R, holds more promise except in Antrycide R resistant strains. In a herd with Naganol R resistance it was effective as a curative and as a prophylactic, but not as successful as Antrycide R (Rottcher et al., 1982; 1983).

Conclusions

There is an urgent need for a new and effective T. evansi trypanocide, but there appears to be little interest on the part of the pharmaceutical industry to develop and produce an additional trypanocidal drug. The available trypanocides, therefore, must be used as effectively as possible. Efforts have to be made to widen their effective scope and to lower their toxicity by combining different trypanocides or to use them in conjunction with other active pharmacological compounds. Attempts to limit the growing development of resistance must continue. As described by Finelle (1973), this is due to underdosing, wrong intervals between prophylactic treatments, discontinuation of prophylaxis in spite of the existing risk of infection, administration of preventive instead of curative dosages and inaccurately calculated injections, all of which need to be carefully avoided.
REFERENCES


DISEASES OF CAMELS IN KENYA


Introduction

A number of disease conditions have been described in the one-humped camel (*Camelus dromedarius*) in Africa. These have been reviewed by Richard (1975; 1979) and Burgmeister (1975). Most of the information on camel disease has been obtained by random sampling of camels on one occasion. Much accurate epidemiological information about disease can be obtained by sequential sampling from small herds of animals (profile herds) over a 12-18 month period.

Some 600,000 camels are present in northern Kenya (Kremu, 1979) and little information is available on disease in the herds which are essential to the livelihood of the nomadic pastoralists in this area. A study was therefore conducted over an 18 month period on four herds in four different areas in Kenya. This study has been fully reported elsewhere (Wilson, Dolan and Olahu, 1981; Schwartz et al., 1982).

Materials and methods

Study herds
The location of the study herds and their herd structure are shown on the map and table 1 respectively. They are designated H1 (Mt Kulal), H2 (Nquurunit), H3 (Ol Maior, Ruruwuri) and H4 (Galana). H1 and H2 were in the arid north of Kenya whereas H3 and H4 were private herds in the south where camel production could expand. H2 belonged to a group of nomadic pastoralists.
Sampling procedures
The frequency of sampling in each herd is shown on table 2 together with the number and type of samples taken at each visit. An attempt was made to sample every animal at each visit; however, this was not always possible especially in H2. All disease conditions were recorded on individual sheets for each camel.

Laboratory procedures
The type of laboratory procedures undertaken on samples are summarised in table 2. A monitoring system was thus established in different age groups for changes in haematological values, measurement of point prevalence rates of trypanosomiasis, brucellosis, camel pox, foot-and-mouth disease and rinderpest, estimation of internal parasite egg output, and tick load according to tick species and estimated number.

Results

Haematology
The results of a between-herd comparison of mean packed cell volume (PCV) and total white blood cell (WBC) levels over the whole study period are shown in table 3. Anaemia and a leucocytosis were present in H1, H2 and H3 whereas H4 showed normal values. Multiple range testing indicated that H2 and H3 were not significantly different for PCV and that H1 and H2 were not different for total white cell counts. Haematological values were normal in H4.

Trypanosomiasis
The point prevalence rate (PPR) at each sampling of trypanosomiasis in all herds as judged by mouse inoculation (MI) and serology are shown in figure 1. Trypanosomiasis was endemic in all herds. PPR as judged by mouse inoculation was highest in H1 and lowest in H4. Trypanosomes of the genus Trypanozoon (probably T. evansi) were most common. However, T. congoense was present at low PPR in H3 and H4. PPR as judged by serology (the
indirect haemagglutination test IHA) was high in all herds over the study period in all herds. A fall in PPR was observed in H1 and H2 and H4 during the dry seasons (May-September; November-February in H1 only). A rise in PPR as judged by both MI and IHA occurred in H3 between June and October 1980 indicating that an epidemic was taking place.

A study on the relationship of trypanosomiasis with age showed that the disease was more common in older animals (see Wilson et al., 1981).

There is adequate epidemiological information to comment on the stability of trypanosomiasis in all study herds. The disease was stable in H2 and H4 as PPR by MI was low and showed little monthly variation, a calfhood resistance was present and PPR by IHA was high in all age groups. The disease was unstable in H1 and H3 as PPR by MI fluctuated, calfhood immunity was not absolute and PPR by IHA was not high in all age groups.

Internal parasitism
The mean herd strongyle egg levels are shown in figure 2. Egg output in H3 and H4 was low throughout the study. The highest levels were detected in H1. Results from 36 larval cultures from all herds showed that Haemonchus contortus was the most common strongyle nematode.

Other nematodes detected included Strongyloides (common in calves), Trichuris (common in all age groups) and Ascaris (uncommon). The cestode Moniezia was also common.

External parasitism
The mean herd tick loads over the study period are shown in figure 3. Low loads were observed in H3 while in H1 ticks were present in large numbers on all camels. The loads in H2 and H4 fluctuated between the two extremes. Further details of this study are reported in Wilson et al. (1981).
Mange due to *Sarcoptes scabei var cameli* was common in calves and immatures in all herds.

**Virus diseases**
Clinical camel pox was observed in the calves of all herds. Incidence of antibody was high in all age groups from all herds indicating that camel pox was endemic.

275 sera and 398 sera respectively were assayed for the presence of antibody to foot-and-mouth disease (FMD) and rinderpest. 2.6 percent and 2.3 percent of animals in H2 and H3 respectively had antibody to FMD (virus types O, C, and SAT2). Only one animal (in H2) had antibodies to rinderpest.

**Brucellosis**
Antibody to *Brucella abortus* was detected in all herds. PPR varied from 38 percent and 6 percent (H3).

**Miscellaneous disease**
A number of other diseases were observed during the study; namely nutritional deficiency, necrotic dermatitis, pneumonia, nasal myiasis enteritis and generalised lymph node enlargement.

**Discussion**
A number of diseases in camels have been identified in this study. Richard (1979) attempted to classify camel diseases in economic terms. His classification in descending order of importance was trypanosomiasis, internal parasitism, mange, pyogenic disease, nutritional deficiency, pulmonary disease, myiasis, camel pox and anthrax. We would agree with this classification with some reservations. Nutritional deficiency in calves was thought to be the most important cause of death in H2; camel pox was probably more important than pyogenic disease in H2-4 and anthrax was not identified as an important
disease in this study. Trypanosomiasis was identified as the most important and common disease of camels in all herds.

The most consistent haematological findings were microcytic anaemia and leucocytosis mainly characterised by a lymphocytosis (H1-H3). Microcytic anaemia is mainly caused by chronic parasitism, a constant finding in all herds. A lymphocytosis indicates constant immunological stimulus which would be consistent with trypanosomiasis due to the property of antigenic variation of this parasite.

The results of PPR's in all herds indicated that trypanosomiasis was stable at low patency levels in H2 and H4 possibly indicating a modifying effect of the host in an endemic disease situation in H2 and a low attack rate due to chemotherapy in H4. The disease was unstable in both H1 and H3 showing large fluctuations in point prevalence rates. The latter herds clearly require the use of drugs to modify the effects of the disease. The results of trypanosome identification show that the camel trypanosome T. evansi is probably the most common parasite, although this is morphologically identical to T. brucei (Hoare, 1972). T. congolense was present in camels in H3 and H4 indicating the presence of tsetse fly, the biological vector of this parasite in these areas.

The differences in herd strongyle levels reflect differences in management, stocking density, parasite attack rates and nutrition. The animals of H3 and H4 under private management with good nutrition and low stocking density had insignificant strongyle levels. However, many animals in H1 and H2 under high stocking density had clinically significant levels of strongyle eggs. The low egg levels in calves (except Strongyloides) probably reflects the long suckling period with minimal contact with faecal contaminated material. Strongyloides is transmitted via the milk. The high levels of strongyle eggs in the adult females of H2 reflect the stress that
these animals are under in a nomadic camel herd. Camel milk is the main human dietary constituent and thus the adult female is under a constant pressure.

The differences in tick loads between herds also reflect differences in management, habitat, stocking rate and nutrition. The high loads in H1 show that monthly acaricide spraying is of limited value, with the effect of habitat being most important. The low loads in H3 and H4 show that weekly use of acaricide grease was of benefit in controlling tick numbers. Loads in H2 were at similar levels throughout the year and did not demonstrate a seasonal effect. The most important tick species varied according to habitat. *H. dromedarii* is important in arid areas being the most important tick in H2. The camel is very important in the life cycle of this tick. The camel is important in the biological cycle of the other main tick species identified and acts as an alternate host to cattle and goats. Tick toxicosis has been reported in camels in northern Kenya and thus the identification of *H. truncatum* in low levels is of importance.

The economic importance of ticks is difficult to measure; however, large mouthpart ticks are more damaging and imbibe greater volumes of blood than small mouth part ticks. 74 percent and 97 percent respectively of ticks identified from H1 and H2 were large mouthpart ticks (*Hyalomma* and *Amblyomma*) and thus the effect of ticks was much greater in these herds than in H3 and H4 where the percentage of large mouthpart ticks was much lower. No haemoparasites were identified in any of the camels in any herd indicating that the main economic effect of ticks is mechanical damage.

Mange is an important camel disease causing loss of condition due to irritation. However, it can be treated with ease by acaricide application.

The most important virus disease of camels is camel pox which was endemic in all study herds. The disease
has been reported to cause heavy calf mortality and once established in a herd is difficult to eradicate. The incidence of the disease increases during the wet season (Cross, 1917) and a lasting immunity usually follows infection. A commercial vaccine is not available for camel pox; however, it would have potential application especially in fully susceptible herds.

According to Richard (1979), the virus of FMD does not appear to affect camels. However, low levels of serological reactors were detected in H2 and H3. There is adequate evidence from these results that the virus could cycle in camels and pathogenesis studies would be required to examine susceptibility in this species.

It is uncertain whether camels are susceptible to rinderpest virus. The virus will cause a slight temperature rise and a stimulation of the immune response (Singh and Ata, 1967; Taylor, 1968) and serological reactors to the virus were detected in a survey of 538 camels in Ethiopia (Richard, 1975). The disease was detected only in H2 in this study indicating that the camel is probably not important as a carrier of this virus.

Brucellosis is known to be an important disease of camels (Richard, 1975; Waghela et al., 1978) and results from this study confirm this view. The role of brucellosis in camel abortions is not known and requires further study.

Control measures for all the main diseases of camels identified in this study are available with the exception of camel pox. A vaccine for camel pox is technically simple and if a market was available could be forthcoming. There is at present only one trypanocidal drug available for the treatment of T. evansi, namely Naganol (Bayer, Germany). Antrycide (I.C.I., U.K.) is very effective but is no longer manufactured although other drug companies are showing interest. A comprehensive disease control package combined with good grazing, breeding and improved milk utilization management should improve productivity in nomadic pastoralist herds.
<table>
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<th>HERD</th>
<th>STUDY PERIOD</th>
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<th>CASTRATE MALE</th>
<th>FEMALE</th>
<th>CASTRATE FEMALE</th>
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Table 2: A summary of period, frequency and type of sampling undertaken on all animals in each herd. The reasons why each sample was taken are also given.

<table>
<thead>
<tr>
<th>HERD</th>
<th>SAMPLING FREQUENCY AND PERIOD OF STUDY</th>
<th>REASONS</th>
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Table 3: An analysis of variance of PCV and total WBC between herds over the whole study period. Herd means are expressed as a percentage for PCV and x 10^2/cumm for WBC:

(A) PCV

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(B) Total WBC

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Figure 1: Trypanosomiasis point prevalence rates judged by MI and IHA in four selected herds of dromedaries.
Figure 2: Mean fecal egg counts (strongyle eggs/gram) on herd basis in four selected herds of dromedaries.

Figure 3: Mean total tick body counts on herd basis in four selected herds of dromedaries.
Map of Kenya, showing location of the four study herds.
REFERENCES


Taylor, W.P. 1968 The susceptibility of the one humped camel to infection with rinderpest virus. Ibid., 16, 405-410.


TOXICITY OF CAPPARIS TOMENTOSA FOR CAMELS

O.F. Idris, Y.M. Salih, A.G.A. Wahbi and Salaheldin E. Abdelgadir

Summary

Four camels (two males and two females) were used in this experiment to investigate the possible toxic effect of C. tomentosa given in a mixture of fruits and leaves as a suspension in water in a dose of 5 g/kg body weight.

The result showed that a mixture of fruits and leaves of C. tomentosa was toxic to camels and that the suspension administered produced toxic effects in the brain, lungs, heart, stomach, intestine, liver and kidneys. A trial has been made to define the biochemical and pathological reasons for the great toxicity of the plant.

Introduction

Capparis tomentosa is a member of the family Capparidaceae which is widespread through tropical Africa from Senegal to Eritrea and southwards to Natal. It is also found in Sudan and on Mascarene Island. It is one of the most popular magico-medicinal plants in Africa. According to Watt and Breyer-Brandwijk (1962) it is used as a purgative in some East African countries and it is also reputed to cure madness. The Zulu are said to chew the plant to counter snake-bites. The leaves are used in Abyssinia as an eye remedy.

In West Africa and Tanzania the plant is considered as a browse plant and is eaten by camels. In East Africa it is said to be fatal to camels and cattle. The fruit is believed to be poisonous in South and East Africa, but the camel eats it willingly (Watt and Breyer-Brandwijk, 1962).
In Sudan, camel owners reported numerous instances of a paralytic disease in camels along the Dinder River in the Blue Nile province. The cases usually terminated in death. Investigations conducted in the area excluded infectious disease. Animal owners blamed an indigenous plant which was identified as *C. tomentosa*.

This study was stimulated by increasing complaints regarding the toxicity of *C. tomentosa* for domestic animals from the central and eastern parts of the country. The problem is of particular importance because the locality is heavily populated with livestock.

Materials and methods

**Animals**

Six clinically healthy camels, divided into three groups of two animals each, were used in this experiment. Animals in group I (one male and one female) acted as controls. Groups II and III (two males and two females respectively), were given a daily dose of 5 g/kg body weight of a mixture of finely divided fresh *C. tomentosa* leaves and fruits as a suspension in water. This was administered by a stomach tube each morning until death.

All groups were kept in pens within the Veterinary Research Administration premises at Soba and were fed on hay and durra grains. Water was provided *ad libitum*.

**Blood sampling**

The animals were bled from the jugular vein. Morning blood samples were collected before drenching in two clean McCartney bottles, one of them containing E.D.T.A. (ethylene diamine tetra-acetic acid) anticoagulant. The other sample was collected without anticoagulant and left overnight at room temperature. The clotted blood was centrifuged and the separated sera were stored at -20°C until analysed. Haemolysed sera were discarded.
Haematological methods
Haemoglobin concentration (Hb) was determined colorimetrically as cyanmethaemoglobin using the haemoglobinometer (Evans Electro selenium Ltd., England). Packed cell volume (PCV) was estimated using the Hawksley microhaematocrit centrifuge. Red blood cell (RBC) and white blood cell (WBC) counts were made with the improved Neubauer Haemocytometer (Hawksley and Sons Ltd., England).

Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) were calculated from Hb, PCV and RBC values.

Chemical methods
Serum sodium (Na) and potassium (K) were determined by flame photometry (Evans Electro selenium Ltd., England) as described by Varley (1969).

Serum iron (Fe) and copper (Cu) were calculated as described by Natelson (1961) and Brown and Hemingway (1962) respectively.

Aspartate aminotransferase (GOT) and alanine aminotransferase (GPT) serum activities were measured by the method of Reitman and Frankel (1957). Serum alkaline phosphatase (SAP) was measured by the method of Kind and King (1954).

Serum creatinine concentrations were measured according to the method described by Owen at al. (1954). Serum urea was estimated by the diacetyl method according to Wootton (1964). Serum bilirubin was measured by the method described by Dangerfield and Finlayson (1953).

Specimens taken at postmortem were immediately fixed in formal-saline. Later they were embedded in paraffin wax, sectioned and stained by haematoxylin and eosin (H and E).
Results

Clinical signs
The first symptoms appear on the third day. They are mainly nervous in character (twisting of the neck into an S-shape, muscular tremors, weakness of fore and hind limbs, stiffening of legs, convulsions, involuntary urination (Plates 1-5). The signs also include anorexia, dyspnoea, incoordination, reluctance to move, nasal frothy discharge, loss of voice, rise in body temperature and hurried respiration. Usually death ensues within twenty-four hours after the first symptoms.

Postmortem findings
Hydrothorax and hydropericarditis are evident. The left ventricle is severely congested. There are petechial haemorrhages in the left ventricle, on the valves, and in the endocardium. In the lungs there are emphysema, pulmonary oedema and congestion. The lymph nodes are congested. The trachea is full of frothy discharge but the oesophagus is normal. The brain is severely congested.

Haematological and chemical findings
These are recorded in Table I. It can be noticed that there is a rise in serum concentrations of Na, K, GOT, creatinine and urea. While a decrease in the values of Cu, Fe, SAP, Hb, PCV, RBC, MCH and MCV is observed, GPT, WBC and bilirubin values do not change. MCHC values are low shortly before death.

Discussion

The present study was initiated to investigate the toxicity of C. tomentosa fed to camels. The criteria for the assessment included mortality and the clinical pathological and biochemical effects.
The results showed that a large proportion of the renal tubule cells were degenerated or necrotic. This suggests a nephro-toxic effect, which probably contributed to the high levels of creatinine, sodium and potassium. The determination of potassium is of greater diagnostic significance because its excretion is in part controlled by the kidney. High levels of serum potassium were observed in goats which had been given copper sulphate (Wasfi and Adam, 1976; Adam et al., 1977).

The liver, being an important organ of the body with several different cell types, reacts to injuries in various ways depending on the nature of the toxic substance used. Attempts to relate structural changes in the liver with functional failure have been made in domestic animals which had been intoxicated with some poisonous plants. Feeding a mixture of fruits and leaves of C. tomentosa caused focal necrosis with infiltration of lymphoid cells in the hepatic, lobular and interlobular septa, resulting in hepatocellular degeneration.

The high levels of GOT and urea concentrations indicate liver cell damage. It is suggested that the increase in the activity of GOT is due to leakage of the enzyme from injured hepatocytes. It is possible that lesions occurring in the kidneys might have also contributed to GOT leakage. Boyd (1962) showed that GOT activity in ruminant tissues, other than the liver, is high. GOT release into the serum of ruminants has been previously observed in dimidium poisoning in cattle (Ford and Boyd, 1962).

Lack of change in GPT activity in serum has confirmed previous findings on this enzyme in the ruminant by Boyd (1962), Ford and Lawrence (1965), Gopinath and Ford (1969), Adam and Magzoub (1975), and Ali and Adam (1978).

Serum bilirubin is not significantly changed in
the experimental camels. This indicates that the ability of the liver to excrete bilirubin remained unchanged (Ford et al., 1968; Adam and Magzoub, 1975).

The development of haemorrhages and erosions in the stomach and intestinal mucosa and the catarrhal enteritis emphasize the severe irritant effect. Some of the constituents of *C. tomentosa* fruits and leaves may have an endothelio-toxic effect.

The evaluation of any neuropathological process is largely dependent on the criteria of significant histological changes. The rapid onset of nervous symptoms and the congestion of the brain capillaries, with gliosis and perivascular cuffing led to the belief that these symptoms may be due to primary involvement of the brain. The severity of the nervous signs during the course of the toxicity might be increased by the hepatic damage.

The lungs were congested, haemorrhagic and oedematous. The dyspnoea was probably due to pulmonary oedema.

The development of anorexia and pallor of the visible mucous membrane and the parallel changes in RBC, Hb, PCV and serum Cu and Fe during the terminal stages suggest hypochromic anaemia as indicated by low MCHC values shortly before death.

The present findings indicate that the fruits and leaves of *C. tomentosa* are toxic to camels by causing structural and functional changes in the brain, lungs, heart, stomach, intestine, liver and kidney of intoxicated camels.

Determination of the character and concentration of the toxic substance in the fruits and leaves of the plant has yet to be done.
Table 1 A: Mean values of two camels in each group during the experimental period.

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Table 1 B: Mean values of two camels in each group during the experimental period.

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Table 1 D: Mean values of two camels in each group during the experimental period.

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Plate 1: Capparis tomentosa poisoning. Twisting of the neck into S-shape.
Plate 2: C. tomentosa poisoning. Weakness of fore and hind limbs accompanied by muscular tremors.

Plate 3: C. tomentosa poisoning. Stiffening of limbs, onset of convulsions.
Plate 4: *C. tomentosa* poisoning. Stiffness progresses.

Plate 5: Pronounced convulsions, preceding death.
REFERENCES

Andrews, F.F. 1950 The flowering plants of the Anglo-
Egyptian Sudan. Vol. 1, p. 41. Published for the Sudan Govern-
ment by T. Buncle and Co. Ltd., Arbroath, Scotland.

Adam, S.E.I. and Magzoub, M., 1975. Toxicity of Jatropha curcas for goats. Toxi-
cology 4, 347.


Ali, B. and Adam, S.E.I., 1978. Effects of Acanthro-
spermum hispidum on goats. J.Comp. Path. 88.


Kind, P.R.N. and King, E.J., 1954. Estimation of plasma phosphatase by determina-


