Storage recommendation for vegetables
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Introduction

The purpose of this survey is to present a series of brief summaries of the essential average storage requirements of vegetables that enter the market on a commercial scale. Many details are necessarily omitted, as this material is intended primarily for general practical reference. The conditions given should not be considered absolute or final, but rather as the safe limitations under which the various products can ordinarily be stored. Detailed information on the handling and storage of some of the commodities discussed is available elsewhere in the form of bulletins or textbooks; for many of them, only general information exists.

Experience tells that optimal storage conditions differ largely in different countries. This is chiefly due to responses. In addition there are also differences between newly harvested products and such that have been transported long distances or been kept at a higher temperature prior to cold storage and such products which have immediately been cooled to a low temperature level.

Fresh vegetables should further be as free as possible from skin damages, bruises, and decay. They should be neither too immature nor overmature, because in either case their storage life may be impaired. The proper degree of maturity can usually be determined by consulting the various recommendations given in this survey. There may also be seasonal variations due to fluctuations in the climatic conditions during growth and harvest.

Decay and other deterioration in storage is too broad a subject to be discussed in detail in this publication; it is merely mentioned in connection with various vegetables covered.

Storage Conditions

More exact conditions are required for the successful storage of vegetables than for top fruits. Since vegetables can
lose moisture very quickly and soon become wilted and unattractive. It is essential to see that the vegetable store is properly constructed. Adequate insulation is necessary and a cooler of sufficient surface area is essential to absorb both the heat produced by the produce itself and the heat that passes into the store through walls, floor and ceiling, without employing an excessively low temperature in the refrigerant.

**Conditions in store rooms**

Recommendations for the best conditions for the storage of fresh vegetables are subject to change from time to time as more definite information is gained in the handling of these commodities. The conditions and requirements given are based on the best commercial practice at the present time and on scientific experimentation.

All temperature requirements are given both in degrees Fahrenheit and Celsius and represent the average air temperatures that should be maintained. The humidities are relative and are expressed in percentage of saturation.

If the best results are to be obtained in the cold storage of the products discussed herein, it is highly important that the temperature in storage rooms be held fairly constant. Variations of 0°C to 1°C (2°F or 3°F) above or below the desired temperature are in most cases too large. The importance of maintaining fairly constant temperatures in cold storage rooms lies in the effect of such control or the lack of it on the keeping quality of stored commodities.

Celery and cabbage allowed to remain too warm in storage may show yellowing and decay; potatoes and root vegetables are likely to begin to sprout if the temperature is too high. Potatoes become undesirably sweet if it is too low. The microflora on the surface of most vegetables also has certain limits for its development. When possible, i.e., as long as physiological disorders can be avoided, storage temperatures have to be kept below the growth minimum of these microorganisms. Other commodities undergo these or other kinds of deterioration if the temperature variations throughout long storage periods exceed the limits given for them in these recommendations.

In addition, fluctuations in temperature will cause condensation
of moisture on stored products, which is undesirable because it favours the growth of mold and the development of decay.

The relative humidity of the air in storage rooms has a direct relation to the keeping quality of the products held in them. If it is too low, wilting is likely to occur in most vegetables; if it is too high, it favours the development of decay, especially in rooms where there is considerable variation in temperature. For leafy vegetables and root crops, the relative humidity should be about 90 to 95 percent; for other vegetables, except as noted, 85 to 90 percent. The exact control of humidity is rather difficult. Earlier it was not often attempted in commercial cold stores, but nowadays efforts are made in many cases to control humidity. By sprinkling the floor it may be raised. More intense air circulation necessitates an increase in relative humidity if wilting of the stored commodity is to be avoided. Doubling the rate of air movement increased moisture loss by about one-third and is equivalent to about a 5-percent drop in relative humidity. The drying effect of an increased rate of air movement is particularly marked, if the humidity of the air is lower than the moisture content of the commodity.

Unless otherwise stated the storage conditions recommended are the optimum for newly harvested products. In later stages when either several days, weeks or months have elapsed since harvesting or a home-refrigerated handling has been practiced, prior to bringing the produce into cold store, completely other recommendations may have to be followed. This has not always been studied sufficiently—and still less attention is paid to this factor.

Under certain circumstances it may be necessary to choose conditions that are not optimum. The storage temperatures recommended are usually as low as is safe or practical, and if an alternate temperature must be chosen, it should in most instances be higher than that recommended. When a higher temperature is chosen, it should be recognized that the storage life will be proportionately shortened, and frequent inspections should be made to determine the condition of the product.

*Mixed storage*

At times it may be necessary to store different products together; experience has shown that this is safe except with some
products where there is a spreading of ethylene or other volatiles. Due to this fruit should never be kept together with leafy vegetables. Additional undesirable combinations are mentioned in connection with the various commodities listed.

Respiration and heat production of commodities

Fresh vegetables are alive and carry on normal respiration even after harvesting. The net result of this process is a consumption of oxygen and a release of carbon dioxide and a production of water. Heat is found in varying amounts due to commodity and the temperature of the product. This heat is always a part of the refrigeration load which must be considered in handling vegetables. The approximate rates of evolution of heat by various commodities are given under each commodity heading.

Some products have much higher respiration rates than others at given temperatures. They require considerably more refrigeration for cooling and maintaining of a cool specified temperature.

When fruits and vegetables cool, the rate at which they produce heat decreases. In order to determine the total amount of heat produced, it is necessary to know the rate of heat production at different temperature levels and the length of time the product is in each temperature range. For example, if the respiration rate (or rate of heat production) for a given commodity is twice as great at 24°C (70°F) as at 10°C (50°F) the number of hours this commodity is at each of these temperatures must be known before the total heat produced can be calculated.

Physiological disorders

Certain vegetables are susceptible to cold injury ahead of reaching the freezing level.

There is a wide variation among commodities in their susceptibility to freezing injury. Some may be frozen and thawed a number of times without permanent injury, whereas others are permanently injured by even slight freezing. The freezing point of the commodity is no indication of the damage to be expected by freezing or chilling. For example, tomatoes and parsnips both have a freezing point of -1°C (30°F), but parsnips can be frozen and thawed several times without
apparent injury, whereas tomatoes are ruined after one freezing. But the lack of injury is only apparent. When the tissue has been frozen – and not only supercooled – it is damaged. Respiration gets disrupted and the product no longer has the characteristics of a living being. Again, mature-green tomatoes will be injured so that they will not ripen properly if held at 32° to 40° for longer than 3 to 5 days, whereas parsnips may be held at 30° for many weeks without deterioration, provided they are not permitted to dry out.

Post-storage effects

There is a belief that cold storage predisposes vegetables to rapid deterioration after removal, but there is no evidence to support this viewpoint except in instances of cold injury. At unrefrigerated temperatures the commodity usually ages quickly and spoilage soon takes place. At refrigerated temperatures these processes are retarded, and the net result is a longer shelf life. As some of the potential life is used up in storage, it is not reasonable to expect the commodity to keep so long after removal as freshly harvested produce; but if the correct temperature and humidity are employed and suitable storage periods are not exceeded, there will be sufficient time for the commodity to pass through the normal marketing channel after removal. Extremely perishable fruits and vegetables have a short storage life and must be used soon after they are taken from storage.

Sweating

When vegetables are removed from a low temperature to a higher one, there is frequently a condensation of moisture from the air on the cool surface of the commodity. This is known as sweating. The higher the relative humidity of the outside air, the more marked is this phenomenon. Generally this favours the development of the surface flora and consequently the decay of the product.

Sweating can be prevented to some extent by allowing the products to warm up gradually. Usually, if the commodity temperature is raised to only 10°C – 11°C (50°F or 55°F) little or no condensation occurs. Under commercial conditions, however, such precautions are rarely practical. Ordinarily, the best procedure in very damp weather
is to handle the product carefully and get it into consumption without undue delay.

Washing

In USA and Canada root vegetables are commonly washed before retailing and sometimes before storage. They are also washed before waxing. Controversial opinions exist as to the risk of contaminations (infections) through washing. Obviously this depends on the amount of infective microorganisms on the root surface. In many cases these are effectively controlled by the addition of 0,1 % sodium-hypochlorite. This chemical chiefly checks bacteria and only to a minor degree those pathogens that cause decay in root crops.

Owing to the high initial cost only growers with large acreages of vegetables are inclined to install mechanical washing equipment. The inadequacy of water supply in many rural districts is another factor restricting the use of mechanical washers.

Waxing

The application of waxing preparations to certain perishable products has been practiced commercially for several years. It probably started with the waxing of citrus fruits and was followed by the waxing of rutabagas. Primarily water losses are reduced. But in most cases an improved appearance seems to be the only advantage.
General references

A. Cold storage


**E. Freezing**


Tressler, D.K., 1947. The freezing preservation of foods. N.Y.

Artichoke
(fr. artichaut)

I. Cold Storage

A. Conditions prior to storage

B. Storing
Optimum temperature: \(-0.5\)\(^\circ\)C to \(0\)\(^\circ\)C (\(31\)\(^\circ\) to \(32\)\(^\circ\)F)
Freezing point: \(-1.7\)\(^\circ\)C (\(29.1\)\(^\circ\)F)
RH: 90 to 95 percent
Commercial storage life: 1-4 weeks

II. Quick Freezing
Not to be recommended.

Asparagus

A. Conditions prior to storage
Growth: Manure and lime improves keeping quality, phosphate deficiencies detrimental.
No great varietal differences.

Handling prior to storage
Clean cutting essential, bruising detrimental.
After a long haul to market, asparagus should not be expected to keep in storage for more than 3 to 6 days, although the preservation of quality will depend largely on how the product was handled before being received for storage.
If spears are washed the end parts should be re-cut to remove contaminating organisms. Knives are to be sterilized in 0.1% hypochlorite.

Precooling: Asparagus that has been precooled immediately after being packed, will arrive at the market in better condition than if not so treated.

Cold water treatment also favourable to quality by lowering respiration level.

**B. Storing**

Optimum temperature: 0°C (32°F). Fresh asparagus deteriorates rapidly at temperatures above 32°F.

Freezing point: -2.1°C (29.8°F) — extremely susceptible to freezing.

RH: 85–95%

Commercial storage life: 2-4 weeks.

The loss of water, while in storage or transit, is likely to be great, if the stalks are not placed on wet moss or other moist, absorbent material in the bottoms of the crates. In storage, asparagus bunches are sometimes set in water in shallow trays. Vapor tight packaging favourable.

Weight loss: 2 – 4%

Physiological changes: Loss in keeping quality closely interrelated to increase in content of acids.

The original tenderness of fresh asparagus, which at ordinary room temperatures is lost soon after cutting due to formation of lignified tissue, is preserved at the lower temperature.

A rapid loss of sugar takes place. The content remains practically the same, as when the asparagus is cut, if put in zero storage immediately after cutting.

Decay: The principle decays of asparagus in storage are bacterial soft rot and gray mold rot. The only efficient control measures is to maintain temperature below +5.1°C (40°F) and avoid bruising.

**II. Quick freezing**

Freeze only tender tips.

Cut spears to 6 inch. length.

Blanching (Scalding): Small stalks 3 min.

Large stalks 4 min.
References

Beans

A. Great varital differences.
Wax beans more adapted to cold storage than green beans.
Nutritional soil deficiencies render products with a low keeping quality.

B. Storing
Optimum temperature: 6 - 10°C (42.8° - 50°F)
Freezing point: -1.1°C.
RH: 85-90 %
Respiration rate: 1,500 cal. per ton day at 0°C and 2,700 cal. at 4.5°C 8,000-11,000 cal./ton day at 15,6°C.
Stacking: The hampers or other containers should be so stacked as to allow abundant air circulation. If the containers are packed close together, the temperature may rise somewhat because of the heat given off by the commodity, and more or less rapid decay may be expected. Open boxes better than bags.
Storage life: 6-10 days at 7,2°C (45°F)
2-4 weeks at 0°C . 4°C (French values)

Physiological diseases during storage:
When held at 4,5°C (40°F) or lower they are subject to definite chilling injury. Pitting develops in 32°F storage after 3-5 days. Chilling injury is reported from USA and Germany but
zero with optimum at 2 to 4°C. Holland gives +4 to +5°C.

Decay: If the beans are stored too long, the pods may become moldy or slimy and stick or "nest" together. The principal kinds of decay favoured by a too high storage temperature or a too long holding period are water soft rot, slimy soft rot, rhizopus rot, gray mold rot, and anthracnose.

C. Post-storage handling

After removal from storage of 3 to 5 days at 32°F to 40°F, russetting usually develops in about 1 day during warm weather. This condition, which is caused by condensation of moisture especially at the centers of the containers, detracts seriously from salability. Marketing should be completed in 1 or 2 days.

Beets (bunched)

B. Storing

Optimum temperature: 0°C (32°F)
Commercial storage life: 10-14 days

Beets (topped)

A. Handling prior to storage

Before going into storage, beets should be topped and well sorted to remove all diseased specimens and those showing mechanical injury in order to prevent undue shrinkage because of storage decay.

B. Storing

Optimum temperature: 0°C (32°F)
Freezing point: -2,8°C
RH: 90-95 %

Stacking: Beets can be stored in ventilated barrels or, better still, in slat crates. Storage in large bulk should be avoided.

Cool air circulation indispensable.
Respiration rate: 662 cal. per ton day at 0°C (32°F)
Commercial storage life: 1-3 months

Physiological changes: Beets are subject to wilting because of the rapid loss of water and should be kept where the humidity is sufficiently high to prevent excessive evaporation.

Broccoli (Italian, or Sprouting)

A. Conditions prior to storage
Icing is an effective way of lowering temperature and decreasing temperature.

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point: -1.5°C (29.3°F)
RH: 90 to 95 percent
Effective air circulation essential
Respiration and heat evolved: 900-1,800 cal. per ton day (0°C)
2,700-4,400 " " " (+4.5°C)
Commercial storage life: 10-21 days
Physiological disorders: Leaves gradually discolor and buds may drop off.
Decay: In humid air black spots. (Alternaria Brassicae)

C. Gas storage
Optimum temperature: -1°C - 0°C (29°F-32°F)
Optimum conditions: 0°C (32°F) +3,5°C (36°F) - 10% CO₂, 11% O₂
Off-flavour in 15% CO₂, 6% O₂
Storage life: 5 weeks.

References:
Smith, W.H. 1940. The storage of broccoli and cauliflower.
J. Pomol. Hort. Sci. 18 (3).
Vol. 113 (5): 41-42
Brussel Sprouts

Icing preferable - reduces weight losses.

B. Storing
Optimum temperature: -3° - 0°C (26,5° - 32°F)
RH: 85-95 %
Storage life: 3-4 weeks (0°C) 8-10 weeks (-3°C)
Weight loss: 20 % - (2 months)

Effective air circulation essential to prevent yellowing and the development of mold.

Cabbage (Head types)
(fr. choux)

A. Prior to storage
Avoid too heavy nitrogen fertilizing - gives products of low keeping quality.
Do not harvest too early or too late.
Most cabbage is kept in clamps or naturally cooled storehouses, insulated to prevent freezing.

B. Storing
Optimum temperature: -2° - 0°C (28,5° - 32°F)
Slight freezing does small harm.
RH: 85-90 %. Cabbage wilts quickly if held under too dry storage conditions; hence, the humidity should be high enough to keep the leaves fresh and turgid.

Respiration and heat evolved: 300 calories per ton day (0°C);
420 calories per ton day (4,5°C)

Storage life: 3-7 months.

Air circulation: Ample air space between tiers should be allowed for ventilation. More ventilating capacity than is required for most other vegetables should be provided to carry away the excessive moisture given off by this product and to obtain the maximum advantage of the cold night air during mild weather.
Stacking: Bin storage is common; usually 4 to 5 feet wide, 10 to 20 feet long, and about 5 feet deep. Bins are best separated by tight board partitions and slat floor for ventilation. Tiers of such bins may be built as high as it is convenient to elevate the cabbages. The use of slat shelves, with heads piled 1 or 2 layers deep, is recommendable, but too expensive for large quantities.

**Cantaloupe (musk melons)**

Picked before table-ripe – shipped under refrigeration.
May be iced.

**E. Storing**

Optimum temperature: Full slip +4 – +7°C (40–45°F)
    **Half slip +7 – +10°C (45–50°F)** in order to ripen in a normal way.

RH: 85–90%

Heat evolved: 330 calories/ton day °C (32°F)
    490   °C (35°F)

Storage life: 1–2 weeks (half slip)
    4–8 days (full slip)

Physiological changes: Softening and breakdown develops and sometimes off- flavours.
The content of saccharose increases and that of starch diminishes.

**Reference:**

**Carrots (bunched)**

Precooling through icing effective.

**E. Storing**

Optimum temperature: 0°C (32°F) 10–14 days.
RH: 85 %.
Poor air circulation hastens yellowing of leaves. Heating of heavily
respiring foliage easily experienced.

**Carrots (topped)**

**I. Refrigerated storage**
(newly harvested)

**A. Conditions prior to storage**

a) Humid and organic soil or high nitrogen gives less keeping quality than dry soil and less nitrogenous ones.

b) Allow to dry on surface.

c) Should be topped and all misshapen or injured specimens sorted out. The latter are especially objectionable, because their presence in a storage lot favours the development of two serious diseases of stored carrots - watery soft rot and bacterial soft rot.

d) Transporting prior to storage increases attacks by rot-producing organisms.

e) Washing may damage surface and make roots unsuitable to storage. Careful washing no detrimental effect.

**B. Storing**

Optimum temperature: 1,1 °C (34°F)

Range: -1 °C to + 4,4 °C (32 °C - 40 °F) 4-6 months; slight freezing not considered injurious.

RH: 90-95 %; improve by wetting boxes or through wet sand. Preferable to use slat crates or ventilated barrels, and provision should be made for air circulation between the containers. Under good conditions they should keep 4 to 5 months.

**II. Gas storage**
(newly harvested)

**B. Storing**

1,1 °C - 4,6 °C (34-40°F) tried with 9 % CO₂ and 12 % O₂.

Growth of shoots and rootlets checked - but more waste through fungal attacks.
III. Refrigerated storage
(ex-clamp roots)

B. Storing
Moved from clamps in late February - early March.
Optimum temperature: 1,1°C (34°F)
RH: 90-95 %
Boxes better than bags - more effective ventilation.
Sprouting - slight even in July.
Chief decay organisms: Sclerotinia spp.
Botrytis inserea
Alternaria radicina
Bacterial rotting negligible.

References:


Cauliflower

A. Conditions prior to storage

Summer types less suited for cold storage than winter types - in other respects small varietal differences.

Not to be harvested under rainy conditions, favours mold development on surface during storage.

Naturing under cool weather gives a better keeping quality than warm weather.

Avoid mature heads; they easily develop a fuzzy or ricey appearance in store.

Leave cover leaf, unless not special prepackaging can effectively substitute.

No heads showing even traces of blackening should be put in store.

Icing aids in keeping fresh.

Leaf abscission during subsequent storage may be prevented by applying 2,4-D naphthalene acetic acid or mixture (50:50) of (50 ppm solution of amylester of this acid with Tween). This solution can also be applied on shredded paper. (50 gr on 1,000 gr).

cont.
B. Storing

Optimum temperature: 0°C (32°F)
  Temperatures above 0°C extremely detrimental. Freezing must be
  avoided, causes a grayish-brown discoloration and softening of the
curd, accompanied by a water-soaked condition.
Freezing point: -1.1°C (30°F)
RH: 85 to 90 percent
Storage life: 12 days + 4°C (40°F)  
  2-3 weeks at 0°C (32°F)  
  6 weeks 0°C (Platenius)  
  8 weeks -1°C (German results)
Weight loss: At 0°C (32°F) 10% in one month. Additional loss are due to
  trimming, indispensable in removing from store.
Stacking: Crates should be stacked with the flower heads down to protect
  the curd from discoloration by dirt and moisture.
Decay: Ozone treatment of air effective against decay.
Physiological changes: Head slowly "matures" during storage. Overmaturity
  is marked by a browning of the otherwise white curd and the deve-
lopment of a rickey appearance. The leaves also become yellowish
  and may drop off. Spraying with certain growth hormones has proved
effective in preventing the dropping of the leaves during storage.
  (See above).
Decay: Blackening of head is a frequent disorder caused by the attack of
  a fungus. Alternaria brassicae. Usually the infection takes place
  in the field. Whenever a head is in contact with the leafstalk or
stem-end of another head a brown area marks the contact surface.
  At temperatures above 0°C (32°F) soft rot develops in this area.

Celery (leaf)

A. Conditions prior to storage
Essential to be as free as possible from infections.

Blanching of the stalks often takes place before putting into storage
  chiefly performed through ethylene treatment (conc. 1/10,000 -
  1/1,000).
Injured and diseased outer leaves are removed.
Packaging: Keeps better in small crates then large ones.
Pre-cooling in cold water favourable; 15-30 min. needed depending on original
  heart temperature.
E. Storing

Optimum temperature: \( -3^\circ C - 0^\circ C \) (\( 31^\circ F - 32^\circ F \))
Freezing point: \( -1^\circ C \)
RH: 90 to 95 percent
Storage life: 2 - 4 months

Air circulation: To be so intense as to maintain an equal temperature at top and bottom of crates. Use dunnage strips between crates and have air channels between the rows.

Stacking: Celery should not be piled more than four crates high provided not store is equipped with forced-air circulation; otherwise, great danger of overheating, even with stock that is in prime condition. If piled 5 to 8 crates high, the room should be observed carefully as to overheating.

Respiration and heat evolved: 404 calories at \( 0^\circ C \) (\( 32^\circ F \)); 605 cal. at \( 4^\circ ,4\circ (40^\circ F); \) 3700 cal. at \( 21^\circ ,1^\circ C \).

Temperature in centre of crate 1-1\(^{1/2}\) C (2-3\(^{1/2}\) F) higher than in the air surrounding the crate. Also 1-2 degrees higher at top of storage room than at the floor, if no air circulation.

Physiological changes: Growth takes place in stalks particularly the central ones lengthen considerably, obtaining their food at the expense of the outer stalks and the roots. A certain amount of blanching takes place in storage.

Decay: Particularly susceptible to watery soft rot. This disease originates in the field and is caused by a fungus that is able to develop to some extent even at temperatures of \( 1^\circ ,1^\circ C \) (\( 34^\circ F \)) to \( 2^\circ ,2^\circ C \) (\( 36^\circ F \)).

C. Post-storage

Some celery is trimmed and washed as it comes from storage. The larger part is moved out in the original crates in which it was received.

D. Freezing is not recommended.

References:


Cucumbers

A. Conditions prior to storage
Large difference from one year to another, and between products from different regions.
Cucumbers grown in the subtropics seem to be somewhat less subject to chilling than those grown in the temperate zones.
Waxing is practiced commercially, usually with a paraffin-carnauba emulsion containing approx. 7% solids: reduces weight loss and improves appearance. If prepackaged, condensation is to be avoided.

B. Storing
Optimum temperature: 7.2°C - 10°C (45°F-50°F). Some authors report good results at 8°C - 4.5°C (Platenius) and 2.5°C (Ulrich)
Freezing point: -0.7°C (30.5°F)

RH: 80 to 95 percent
Storage life: 2 - 3 weeks
Respiration and heat evolved: 4,200 cal. per ton day at 0°C (32°F) and 6,400 cal. at 4.5°C (40°F)
Physiological changes: When held at 7.2°C (45°F) or below for longer periods than recommended, surface pitting or dark-coloured watery areas appear. These blemishes indicate low-temperature or chilling injury. Such areas soon become infected, and they decay rapidly on removal to warmer temperatures.

Slight chilling injury has been noted at 0°C (32°F) in 2 days, and severe injury within 6 days. If the cucumbers are held at 10°C (50°F) little or no breakdown develops, but they tend to ripen rather rapidly, the colour changing from green to yellow, and there may be some shrivelling and surface pitting.
Eggplants
(fr. aubergine)

A. Storing
Optimum temperature: 7,2°C - 10°C (45°F - 50°F)
Freezing point
RH: 80-85 %
Storage life: 10 days

Physiological changes: Surface pitting or bronzing, especially near the stem end, if temperature below 7°C (45°F). Develops only after some days. The pits sometimes occur in groups that coalesce into larger sunken areas.

Endive, or Escarole

A. Conditions prior to storage
Icing preferable.

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point:
RH: 90-95 %
Storage life: 2-3 weeks

Physiological changes during storage: A certain amount of desirable blanching takes place.

Garlic, dry
(fr. ail)

Should be dried on surface.
Essential that garlic be well cured in the field before going into storage.
Preferably packed in loose mesh bags.

B. Storing
Optimum temperature: 0°C (32°F)
RH: 70-75 %
Storage life: 6-8 months
Stacking: Piled 2 layers deep in stacks, separated by air spaces.
Horseradish
(fr. raifort)

Roots dug early still in active growing, do not store well.
Should be conditioned by cold weather before dug.
Do not store wet roots.
Has to be topped.

B. Storing
Optimum temperature: -1°C - 0°C (30-32°F)
RH: 90-95 %
Storage life: 10 - 12 months.

Kohlrabi

A. Conditions prior to storage
Allow to dry on surface
Should be topped and all misshapen or injured specimens rejected.
No washing.

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point: -1,1°C (30°F)
RH: 90-95 %
Storage life: 2 - 4 weeks.

Leeks, green
(fr. poireau)

A. Conditions prior to storage
Trim tops as needed, all injured or diseased leaves should be removed.
Should be crated.

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point: -1,5°C (29,2°F)
RH: 90-95 %
Storage life: 1-3 months
Root ends are sometimes lightly and occasionally moistened.
Physiological changes: Green colour of product gradually fades as chlorophyll breaks down, resulting in a successive yellowing.
Lettuce

Harvesting preferably during night or early morning.
To be trimmed removing all damaged or discolored leaves.

Washing may favour decay and is in most cases to be postponed until the storing period is at an end.

Prepackaging chiefly at the marketing level. Special machinery has been developed. Bags mostly used and sealed.
Packaging material: Cellophane, polyethylene and stretchable Plio film.

Precooling essential
Icing preferable - prevents drying or wilting.
Vacuumcooling has in US turned out to be a commercial proposition with lettuce. - In 15 min. the desired vacuum (4,6 mm Hg) is reached in vacuum-coolers and in 50 min. internal lettuce head temperature is down to +1°C (33-34°F).

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point: -0.5 - -0.6°C (31°F)
RH: 90-95 %
Heat evolved: 2.800 calories/ton day at 0°C (32°F) and 4.000 " " " 4,5°C
Storage life: 1-3 weeks

Physiological changes: Certain polysaccharides are converted into sugar, these preserving the sweet taste of the leaves. Too rapid loss of water from the leaves causes a tipburn localized to the edge of the top leaves. They show a brown border along the edge of the leaf.

Decay: In transit and storage may develop a type of tipburn in the interior of the head. This injury may also appear in the field. In later stages of marketing it is frequently followed by a slimy bacterial decay, which may result in serious damage. Frequent inspection of stored lots is desirable.
Melons
(Honey dew)

A. Conditions prior to storage
Picking should be done early in the morning or night.
Remove obviously immature or over-ripe specimens.
Should be put in boxes or crates.
May need washing to remove dust, dirt or spray residues.

Refrigeration chiefly practised at terminal markets.

B. Storing
Optimum temperature: 7-10°C (45-50°F) (US)
2-3°C (34-35°F) (France)

Storage life: 2-4 weeks
Physiological changes: US-varieties susceptible to temperature below 7°C (45°F). Breakdown develops gradually.


Mushrooms, Cultivated
(fr. Champignons de Paris)

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point: -1°C (30.2°F)
RH: 85-90%
Heat evolved: 1,540 calories per ton day at 0°C (32°F);
5,500 " " " " +10°C (50°F)
Storage life: 5 days (0°C) 2 days (+4.5°C)(40°F)

Physiological changes: Deterioration is marked by brown
discoloration of the external surface and by opening
of the veils.
Onions
(oignon)

A. Conditions prior to storage
Great varietal differences - as a rule early varieties keep less
than late varieties. Those with low water content generally store best.
Consult experiment stations as good keepers. They generally transpire
less and have a high proportion disaccharides as compared to mono-
 saccharides.
Excessive manuring diminishes the keeping quality.
At their best for storage, when fully mature (leaves have flattened
and become withered)
Treatment in the field by spraying with maleic hydrazide prevents
subsequent sprouting. (A detrimental effect is reported by Rehm
after such treatment obtaining products more liable to rotting.)
Should be well dried, or cured, in the field for 4 to 6 weeks;
should be frequently turned, particularly after rainy or damp weather.
Careful sorting to remove all diseased or damaged bulbs. Reject also
those showing thick, or "bottle", necks.

The use of sodium sulphite tablets or diphenyl wrappers did not
control wastage through black mould.
Usually held in open-mesh-sacks of 20-25 kg (50 lbs) or 45-50 kg
(100 lbs) each, or shallow slatted trays.

B. Storing
Optimum temperature: 0°C (32°F) -2°C (28,4°F)
Freezing point: -2°C (28,4°F)
RH: 70-75 % - with forced air circulation 85 % is possible.
Heat evolved: 230 calories per ton day (0°C). Yellow Globe: 165-275
calories per ton day at 0°C, 440-455 at 10°C (50°F) and
770-1040 at 21°C (70°F).
Weight loss: 0,3 % (32°F), 1,7% (55°F)
Stacking: Bags are best piled in pairs laid crosswise in stacks 5 or 6 sacks high. The stacks should be set a few inches off the floor on 2 by 4-inch strips and the individual stacks separated by a few inches of space to allow air circulation.

Still better to put mesh bags with onions only in one layer and arrange wooden structure to create a 2nd and 3rd extra floor. Air space between each layer about 6-7 inches.

Main storage problems: Wastage, root growth and desiccation.

Decay: In humidities above optimum onions are disposed to decay. The commonest disease is gray mold rot ( ) sometimes called "neck rot" as it frequently occurs at the top of bulb. This fungus is often psychrophilic (78). No fungal wastage up to 12.8°C (55°F) according to S.African results (Beyers).

Physiological changes: Dormancy lasts up to two months. Sprouting difficult to check even at 0°C (32°F) after 9 months of cold storage. Zero centigrade necessary to avoid sprouting. Light favours sprouting.

In humidities higher than optimum onions are disposed to root growth. As a whole root growth is favoured by humidity and sprout growth by temperature.

Surface drying advantageous: - gives an increased market value by the development a copper tinted colour - and it stops effectively fungus growth.

Onions are not perceptibly injured by slight freezing, if allowed to thaw out slowly and without rough handling. They may be characterized as moderately susceptible to cold storage temperature.

Total sugars and sucrose diminishes during storage.
Susceptible to ammonia vapour from refrigeration machinery.

C. Gas storage

According to German results not to be recommended.

Storage in nitrogen atmosphere of yellow varieties (with only 0,5% oxygen) gives, however, a favorable response.
D. Freezing not recommended.

E. References:


Onion Sets
(oignon de semence)

A. Conditions prior to storage

Curing: Special heat treatment e.g., 1-2 months at 25-30°C (77-86°F) gives an additional yield (54-59%) at growing after end of storage period.

Packing: Best stored in shallow slatbottom crates or trays not over 4 inches deep and about 5 by 5 feet in some districts or 2 by 3 feet in others. The corner posts of the crates should project about an inch above the side pieces to prevent the crates from resting tightly on each other, when stacked and to allow air circulation between them.

B. Storing

Mostly in common storage, only occasionally in refrigerated stores.

RH: 70-75%

Storage life: 6-8 months

Stacking and air circulation:
Because of their size, onion sets tend to pack closely in the crates hence it is essential to allow as much air circulation as possible and to maintain a comparatively low humidity.

Reference:
Anon. Statens Forsøgsvirksamhed, Hornum, (research reports) - yields after heat treatment of onion sets.
Parsnips (topped)
(fr. panais)

A. Conditions prior to storage
Should be topped.
Washing is effective in preventing wilting.
Susceptible to drying, preferable to store in moist sand or clean soil to prevent wilting. Keep however in good condition in barrels or crates.

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point: -1.1°C (30°F)
RH: 90-95%
Storage life: 2-4 months

Physiological changes: Parsnips dry out readily in storage; hence, it is essential that the humidity will be kept relatively high.

They are not injured by slight freezing but have to be protected from hard freezing and should be handled with great care while in a frozen condition. Some authors represent the view that freezing improves the flavor.
Peas, Green

A. Conditions prior to storage
Nitrogen detrimental to keeping quality, potash and phosphate favorable.
Mechanical injury highly detrimental, rapidly creates off-flavour.
Packed in mesh bags
Icing highly favourable
Keep better unshelled

B. Storing
Optimum temperature: 0°C (32°F)
Freezing point:
RH: 85-90%
Storage life: 1-2 weeks (US) 4-8 weeks (German results)

Physiological changes: Unless rapidly cooled, they lose a substantial part of their sugar content.
Potatoes, early
(fr. pomme de terre précoces)

A. Conditions prior to storage

Generally cold storage is not practiced.
Should be picked up within 15 - 20 minutes after dug - this is especially important on dry, windy days.
Should be sorted carefully before storage to remove all that are decayed, seriously bruised, or cracked. Prior to refrigerated storage at 10°C (50°F) a curing period for wound healing is best for earlies.
Handle gently to avoid all bruises and other mechanical damages.
Washing gives good results tubers are immediately dried on the surface.
Icing has a favourable effect.
Mesh bags should not be used, give bag marks on the potatoes.

II. Storage

Optimum temperature: 2-4.5°C (35.6-40°F)
RH: 85-90%
Decays: Bacterial soft rot results from injury by heat (e.g. from the sun)
Should be kept in the dark to prevent greening through production of chlorophyll. This goes parallel to formation of solanin, which has toxic properties.

Reference:
USDA, Circular No. 744, 44 pp.

Potatoes (late crop)
(fr. pomme de terre, tardive)

Chiefly stored in common storage, good potato may be kept in cold store. Under warm extreme conditions (spring and summer) refrigeration may be useful.

A. Conditions prior to storage

Excessive nitrogen detrimental; potassium improves keeping quality.
Often to be recommended to keep potatoes at 13-16°C (55-60°F) for 1-2 weeks prior to cold storage to allow wound healing or "curing". Tubers carrying brown rot infections cannot be treated in this way and have to be cooled down immediately in order to check growth of this decay fungus, but attacks can only be postponed for a shorter period.

Potatoes from fields infected by blight are usually not suitable for storage, as the blight fungus will spread in storage even if all obviously diseased tubers have been sorted out. If the field infection occurs late in the season, no evidence may be apparent on the tubers but extensive rot may develop soon after storage.

Stored in sacks or bags or in bulks, placed in bins.

Potatoes intended for storage should be handled carefully to prevent bruises and cuts; otherwise they are likely to be damaged by various forms of decay before the end of the storage period.

Washing frequently practiced in US - afterwards they do not keep for any appreciable period of time. There is a difference of opinion regarding the necessity of drying potatoes after washing but this is in most cases done. After drying they may be waxed.

**B. Storing**

Freezing point: -1.7°C (29°F)

RH: 85-90 %

Weight loss: 2 % (5 months)

Physiological changes: If kept below 4.5°C (40°F) sugar accumulates in tubers. By holding 1-3 weeks at room temperature the natural flavour is restored.

Seed stock can be maintained at 2-3°C (35-38°F) as flavour change has no importance. Different varieties react by increased resp. diminished yield through such treatment. After being dug most varieties show a rest-period of 2-12 weeks. Can, however, be kept at 40°C for 5-6 months.

Should be kept in dark to prevent greening and formation of solanin.

Light also hastens sprouting.

A humidity lower than 80 % gives an excessive shrinkage of tubers. Reachly injured even by slight freezing.

Temperatures of 0°C (32°F) are often detrimental. In addition respiration shows an optimum at 4.5°C (40°F). The respiration rate at 0°C is often at the same level as at 10°C (50°F).

Commercial sprout inhibitors as tetrachloronitrobenzol and isopropyl-phenylcarbamate (30 %) are sometimes used to prevent sprouting where
the storage temperatures are too high to prevent it. When used as directed, these are effective at temperatures even as high as 15°C (70°F) and apparently do not affect the table quality. Should generally not be used on seed potatoes. Maleic hydrazide can be applied by field sprays 3 weeks prior to harvesting when leaves still are green.

Tubers emit volatiles which inhibit germination.

Potatoes that have been kept at 40°F (4.5°C) for a long time are seldom suitable for processing, such as chip making, french frying or dehydrating, without first being conditioned to reduce the quantity of sugar, that has accumulated. This is accomplished by holding the potatoes at 21-27°C (70-80°F) until trial cooking tests show that they have recovered sufficiently for use. The length of the conditioning period will depend on the variety and the amount of sugar that has accumulated; usually this will be 1 to 3 weeks. Not all varieties of potatoes are suitable for chipping or for french frying.

C. Gas Storage

Good results from 5-10% CO₂ and 15-10% O₂ at 7°C (44.6°F)

References:


Pumpkins and Squashes
(fr. potiron et gourde)

Large varietal differences. Should be well matured and carefully handled. Immature specimens should be ripened by curing at 26,6°C - 29,4°C (80-85°F); this treatment gives an effective healing of all injuries. Careful sorting, rejecting all injured or decayed. Stems should be removed.

E. Storing
Optimum temperature: 10-12,8°C (50-55°F) (wintersquash)

0-4,5°C (32-40°F) (summersquash)

Freezing point: -1,0°C (30,1°F)

RH: 70-75 % (wintertype); 85-95 % (summertype)

Storage life: 2-6 months

Reference:

Radishes
(fr. radis)

A. Conditions prior to storage

Precooling effective
Icing favourable
Waxing gives good results.
B. Storing
Optimum temperature: 0°C (32°F)
RH: 90-95 %
Storage life: 3-4 weeks (topped 4-6 weeks)

References:
Anon. 1954. Prepackaged waxed radishes point the way on processing root crops. Pre-Pack-Age., Vol. 7(8) p. 22-23.

**Radishes**
* (black - winter type) *(fr. radis d’hiver)*

**A. Conditions prior to storage**

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B. Storing
Optimum temperature: 0°C (32°F)
RH: 90-95 %
Storage life: 2-4 months

**Rhubarb**
* (fr. rhubarbè)*

**A. Conditions prior to storage**

Bunches should be packed in crates.

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B. Storing
Optimum temperature: 0°C (32°F)
Freezing point: 1,9°C (28,4°F)
RH: 90-95 %
Storage life: 2-3 weeks

**Stacking:** Ample air circulation on all sides essential; otherwise there is danger of heating and mold growth.
Rutabagas

A. Conditions prior to storage

Waxing frequently practiced; appearance is improved; wilting and loss of weight diminished.

B. Storing

Optimum temperature: 0°C (32°F)
Freezing point: -1,5°C (29,1°F)
RH: 90-95 %
Storage life: 2-4 months

Spinach
(fr. épinard)

A. Conditions prior to storage

Excessive nitrogen highly detrimental to keeping quality.
Dirty, dead, yellowed or diseased leaves should be removed.
Washing should be avoided until after storage.
Icing has favourable effect, at any rate keep moist.

B. Storing

Optimum temperature: 0°C (32°F)
Freezing point: -1,1°C - -0,5°C (30-30,5°F)
RH: 90-95 %
Storage life: 10-14 days
Respiration and heat evolved: 1,000-1,200 calories per ton day at 0°C;
1,700-2,800 calories per ton day at +4,5°C;
4,400-5,200 calories per ton day at +10°C
and 9,100-9,500 at 16°C

Stacking: Free air circulation is essential
Physiological changes: Freezing detrimental
Decay: Slime easily develops on leaf surface.

Butyric acid fermentation starts easily in prepackaged products.
A. Conditions prior to storage

Great varietal differences.

"Curing" necessary prior to storage - to be held at temperatures of 28-30°C (82-86°F) and a RH 85% - this in order to heal all wounds or abrasions, unavoidable during harvesting and handling - generally takes 8-10 days.

They are frequently waxed but generally only when prepared for market.

B. Storing

Optimum temperature: 13-16°C (55-60°F)
RH: 80-85%
Respiration and heat evolved: 297-610 calories per ton day at O°C
Stacking: Either in shallow bins or slat crates.
Physiological changes: Shorter periods below 12°C (55°F) need cause no alarm but longer periods give a chilling injury and subsequent decay.

References:


Tomatoes

A. Conditions prior to storage

Great varietal differences.

Phosphorus deficiency gives products of low keeping quality.
Stalls should be left, such fruit better maintained during subsequent storage.
B. Storing
Optimum temperature: 10°C (50°F) (ripe) 12.8-21.1°C (55-70°F) (mature green)
Freezing point: -0.3°C
RH: 85-90 %
Storage life: 1-3 weeks (ripe) and 4-6 weeks (mature green)
Respiration and heat evolved: 145-250 calories per ton day at 0°C (32°F); 265-315 " " " 4.4°C (40°F); and 1.410-1.560 " " " 15.6°C (60°F).

Physiological changes: Susceptible to temperatures below 10°C. Such chilling injury takes time to show, so a shorter period (1-2 days) apparent injury. Breakdown takes place, which encourages decay or abnormal softening (soft watery spots in pulp). Green tomatoes kept below 10°C for more than 5 days do not ripen at room temperature.
Taste changes often develops during storage.
Ascorbic acid content lower in green tomatoes ripened in store compared to those left on the vine.

C. Gas storage
According to Kidd and West gas storage retards coloration.
Effective concentrations are 2.5 % oxygen, 10 % carbon dioxide and 5 % oxygen, 5 % carbon dioxide. Room tests were made at 12°C.

References:
Murlong, C.R. 1946. Agriculture, p. 313


Sando, C.B. 1920, USDA Bull. No. 859


Topinambour (Jerusalem artichoke)

I. Cold storage
A. Conditions prior to storage

B. Storing
Optimum temperature: -0.5 - 0°C (31°F - 32°F)
Freezing point: -3°C (27.5°F)
RH: 90-95%
Storage life: 2 - 5 months.

At low humidities they shrivel badly and are more likely to decay than if kept in a moist atmosphere.

Stored in barrels or in paper-lined bags they keep longer with loss wilting and decay than if left in open containers.

II. Quick freezing
Not to be recommended
Turnips
(fr. navet)

A. Conditions prior to storage
Should be topped

B. Storing
Optimum temperature: 0°C (32°F)
Freezing Point: 0.8°C (30.5°F)
RH: 90-95 %
Storage life: 4 - 5 months
Respiration and heat evolved: 405 calories per ton day at 0°C and
537 calories per ton day at 4.5°C.

Watermelons
(fr. )

A. Conditions prior to storage

B. Storing
Optimum temperature: 2.2-4.4°C (36-40°F)
RH: 85-90 %
Storage life: 2-3 weeks
Physiological changes: Tend to be pitted or dented after one week
below optimum. Some varieties develop objectionable flavours.