

Innovative Milk Foamer

Stefan Axelsson

Product Development



INSTITUTE OF TECHNOLOGY
LINKÖPING UNIVERSITY

Master Thesis

Department of Management and Engineering

LIU-IEI-TEK-A--10/00863--SE

Innovative Milk Foamer

Stefan Axelsson

Product Development

Fellow adviser at Linköpings Tekniska Högskola: Simon Schütte

Fellow adviser at Electrolux floor care and small appliances AB: Henrik Eriksson

Master Thesis

Department of Management and Engineering

LIU-IEI-TEK-A--10/00863--SE

Abstract

This report presents the primary development process of an innovative milk foamer. The project is structured as the primary development process that is used at Electrolux Floor Care and Small Appliances AB, Global Primary Development and Innovation department in Stockholm, Sweden. The aim was to develop a milk foamer with innovative solutions to provide Electrolux with a unique product. The objective was to create a product that highly meets customer requirements and in the same time is feasible to develop into a selling product. All the aspects regarding a consumer product had to be considered. To create innovative solutions thorough investigations of the physics behind foaming and foam are studied and documented. The difference in foam quality when using different ways of foaming is documented and possible explanations is discussed. The primary development process range from pre-study and customer research to designing prototypes and verifications. Most of the report deals with standalone solutions but there is also a part of the report that deals with integrated solutions and cooperating solutions that would be used together with espresso machines. The result is a variety of concepts and four fully working standalone prototypes. Two prototypes are further developed and are highly interesting to Electrolux.

Acknowledgments

A very special thanks goes out to my fellow adviser Henrik Eriksson, project manager at Electrolux Floor Care and Small Appliances AB, Global Primary Development and Innovation department in Stockholm, Sweden, whose assistance and support have been of great help.

I would like to express my gratitude to everyone at Electrolux Floor Care and Small Appliances AB, Global Primary Development and Innovation department in Stockholm, Sweden, for the assistance they provided at all levels of the project. It has been delightful to work in such an inspiring environment and I have learned a lot.

Johann Zita, Global Primary Development and Innovation Manager

Stefan Jonsson, Project Manager

Fredrik Sjöberg, Project Manager

Håkan Miefalk, Project Manager

Anders Haegermarck, Consultant

I must also acknowledge Mathias Behlin, Technical Area Manager, Martin Andersson, Test Engineer and Anders Ekman at Electrolux Floor Care and Small Appliances AB, Global Primary Development and Innovation department in Stockholm, Sweden, for the special help they have provided me with this project.

Also a big thanks to:

Kaveh Azizian, Swedish barista champion

Evi Hessenauer, Home economist – Primary Development Cooking

Reiner Horstmann,

I would also like to thank my fellow advisor Simon Schütte at Linköpings Tekniska Högskola.

Finally, I would like to thank Per Johansson and Nils Knutsson at Linköpings Tekniska Högskola for great help with manufacturing parts to prototypes.

Table of Contents

1	Introduction	1
1.1	Background.....	1
1.2	Problem.....	1
1.3	Methodology	1
1.4	Acronyms.....	3
2	Purpose and aim.....	5
3	Pre-study	7
3.1	Barista trends	7
3.2	Milk foam	7
3.3	Physics behind foaming milk	15
3.4	Existing tests and evaluations of milk foam and milk foamers	18
3.5	Modified tests and evaluations of milk foam and milk foamers.....	20
3.6	Market analyse	22
3.7	Patent scan	24
3.8	Customer research	25
4	Creation of ideas	29
4.1	Brainstorming meeting	29
4.2	Ideas and evaluation.....	29
4.3	Elimination process.....	38
4.4	Decision matrix.....	39
4.5	Ideas to bring to the next phase.....	39
5	Solution and verification	41
5.1	.....	41
5.2	.....	47
5.3	.....	50
5.4	.....	50
5.5	.....	52
5.6	Strength calculations	54
5.7	Ideas to bring to the next phase.....	59
6	Hardware and solutions.....	61
6.1	.....	61
6.2	.....	61
7	Results.....	63
7.1	Pre-study	63
7.2	Creation of ideas.....	63
7.3	Solution and verification	63
7.4	Hardware and solutions	64
8	Discussion.....	65
8.1	Pre-study	65
8.2	Creation of ideas.....	65
8.3	Solution and verification	65
8.4	Hardware and solutions	66
9	Recommendations and how to continue with the project	67

10	Conclusions	69
11	Vocabulary	71
12	Reference List	73

Appendix A:	Gantt Timetable	A-1
Appendix B:	Photos of foam	B-1
Appendix C:	[REDACTED]	C-1
Appendix D:	Images of foams	D-1
Appendix E:	Bubble size of foams	E-1
Appendix F:	International standard	F-1
Appendix G:	Lab standard	G-1
Appendix H:	Main tests	H-1
Appendix I:	Patent scan	I-1
Appendix J:	General survey	J-1
Appendix K:	General survey answers.....	K-1
Appendix L:	Kano survey	L-1
Appendix M:	Kano survey answers.....	M-1
Appendix N:	Kano diagrams	N-1
Appendix O:	Rough material scan.....	O-1
Appendix P:	Conversation with Reiner Horstmann regarding concept 17	P-1
Appendix Q:	CAD-models, [REDACTED]	Q-1
Appendix R:	CAD-models, [REDACTED]	R-1
Appendix S:	QFD [REDACTED]	S-1
Appendix T:	QFD [REDACTED]	T-1
Appendix U:	Electric scheme	U-1

Table of Figures

Figure 1: Electrolux Primary development process.....	2
Figure 2: Surfactant molecules lined up on water surface (Hoffmann, 2006).....	7
Figure 3: Texture of frothed milk, bad foam (left) and properly frothed milk, microfoam (right)	9
Figure 4: Images of foam formed at 45°C.....	14
Figure 5: Bubble cut in two halves displaying acting forces.....	17
Figure 6: Multiple light scattering coupled with vertical scanning.....	19
Figure 7: OBH Nordica Café crema.....	22
Figure 8: Nespresso Aeroccino.....	22
Figure 9: Bialetti Tutto Crema	22
Figure 10: Stovetop steamer	23
Figure 11: AEG Crema Classica.....	23
Figure 12: Easypress.....	24
Figure 13: Lavazza Cappuccinatore.....	24
Figure 14: Different nozzles	29
Figure 15: Nozzle that makes the milk rotate	30
Figure 16: Whisk run by steam	30
Figure 17: Friction foamer.....	31
Figure 18: Jug with a non flat bottom	31
Figure 19: Steamer application.....	32
Figure 20: Induction heated whisk	32
Figure 21: Ball loaded with steam	33
Figure 22: Shaker prototype	33
Figure 23: Rotato	33
Figure 24: Air sling whisk prototype.....	33
Figure 25:	34
Figure 26:	34
Figure 27:	35
Figure 28:	35
Figure 29: Whisk with heat.....	36
Figure 30:	36
Figure 31: Construction that drags down foam	37
Figure 32: Prototype to verify what different influences drag and press has on the creation of foam	37
Figure 33: Composition of the concepts that will be investigated further	40
Figure 34:	41
Figure 35:	41
Figure 36:	42
Figure 37: Prototype made out of Nespresso Aeroccino	46
Figure 38: Prototype made out of OBH Nordica Latte Pronto	46
Figure 39:	46
Figure 40: This is the final construction of the prototype, it is built in ABS-plastic	49
Figure 41:	49
Figure 42:	50
Figure 43:	50
Figure 44:	50
Figure 45:	51
Figure 46:	53
Figure 47:	53
Figure 48:	54
Figure 49:	54
Figure 50:	54
Figure 51:	55
Figure 52:	64
Figure 53:	64

Table of Diagrams and Tables

Diagram 1: Foamability of different sorts of milk as a function of temperature (5–85°C).....	12
Diagram 2: Foam stability of different sorts of milk as a function of temperature (5–85°C).....	13
Diagram 3: Surface tension of different sorts of milk as a function of temperature (5–85°C).....	15
Diagram 4: Customer requirements, x-axis displaying percent.....	26
Diagram 5: Kano better-worse diagram.	27
Diagram 6: [REDACTED].....	43
Diagram 7: [REDACTED].....	43
Diagram 8: Bubble diameter-Part foam diagram.....	44
Diagram 9: Schwarzer 270 EC-TH with flow-pressure diagram.....	45
Diagram 10: Tension of flat bar with hole	55
Diagram 11: User friendly-Foam quality, displaying products on the market and prototypes (bold).....	59
Table 1: Evaluation of different milk foamers	24
Table 2: Elimination process regarding integrated concepts	38
Table 3: Elimination process regarding cooperating concepts.....	38
Table 4: Elimination process regarding standalone concepts	38
Table 5: Decision matrix	39
Table 6: [REDACTED].....	42
Table 7: Properties of interesting materials	47

1 Introduction

To achieve a Master of Science degree in Mechanical Engineering with orientation product development from Linköpings Tekniska Högskola this final master thesis was performed at Electrolux Floor Care and Small Appliances, Global Primary Development and Innovation department in Stockholm, Sweden.

With pleasure the opportunity to perform this final master thesis at one of the global leader in home appliances and appliances for professional use was accepted. Electrolux sells more than 40 million products in more than 150 markets every year. Electrolux products include among others cookers and cooktops, ovens, fridges and freezers, dishwashers, washing machines, tumble dryers, room air conditioners and vacuum cleaners. (Electrolux, 2010).

1.1 Background

At this time some of Electroluxs small appliances are not directly developed by Electrolux. As design and construction is important to Electrolux this is about to change.

Milk foam is needed to create different sorts of coffee specialties. As coffee drinks is a part of the trend and lifestyle it is important that the milk foamer gives the right affective feeling. Many of the existing milk foamers today look the same and do not stick out, nor create high quality foam. Electrolux wish to develop a unique innovative milk foamer that meets customer requirements and that process starts with the primary development.

1.2 Problem

The main problem is how to produce high quality foam and heat the milk. Sub problems involve solving the main problem without compromising how easy the product is to clean and use.

1.3 Methodology

Electrolux uses a process called Product Creation Process (PCP) when creating new or next generation products. A part of the PCP-process is the Primary Development (PD) phase, see Figure 1, and the overall purpose of this phase is to reduce uncertainties by systematic testing of new potential technologies. It is also an innovative phase where new ideas and solutions are born, developed and verified. The output of the Primary Development phase is a verified solution to a core problem, evaluated and tested with functional prototypes (Product Creation Process, 2003). In this project the same primary development (PD) process used by Global Primary Development and Innovation department in Stockholm has been used. Although the development process has been slightly modified to suite this project, it is structured with the four phases and checkpoints. A checkpoint meeting was held in the end of every phase, the steering group decided which ideas to investigate further and what direction to take. The steering group consisted of: Stefan Axelsson, Johann Zita, Global Primary Development and Innovation Manager, Henrik Eriksson, Project Manager, Mathias Belin, Technical Area Manager, Martin Andersson, Test Engineer and Mathieu Sainte Beuve, Product Marketing Manager.



Figure 1: Electrolux Primary development process

1.3.1 Pre-study

The pre-study started with a time plan, phases and important tasks was structured in a Gantt timetable (see Appendix A: Gantt Timetable). In the starting phase relevant and useful information and theory regarding milk and milk foamers are studied and documented. This part will basically serve as the theory part of a technical report. As this is a development process all the theory needed was not known from the start and therefore a few theories will be added along the way to make a more natural flow in the reading. A benchmarking and patent scan took place early in the project to get a picture of what already exists on the market. To get an insight in products and their performance a discussion with the employees at the store Kaffemaskinen was held. Products in other areas involving whisking and heating were also investigated. A teambuilding /education was held with the Swedish barista champion Kaveh Azizian, this gave valuable information from a highly respected person in the area. Customer research was made in form of two surveys, one general and one Kano survey, to understand what performance customers expects of a milk foamer. Furthermore, an information foundation was established through internal Electrolux documentation. The information foundation contained, general milk foaming functions and lab standards.

1.3.2 Creation of ideas

After the pre-study was done the most creative phase took place involving idea generation mainly using brainstorming. To generate as many ideas as possible a brainstorming meeting with the primary development department at Electrolux Floor Care and Small Appliances AB, was performed. To verify if the different ideas were feasible and realistic rough prototypes and tests were made. An elimination process was done where all the unfeasible and unsatisfying ideas were rejected. Feasible concepts were ranked and evaluated using a decision matrix. The idea generation phase is iterated until a satisfying concept is found.

1.3.3 Solution and verification

Concepts that made it to this phase are more thoroughly investigated, verified and evaluated. Working prototypes were constructed and manufactured to be able to evaluate the concepts.

1.3.4 Hardware and solutions

At this phase prototypes are further improved so that the performance close to the one at a final product can be investigated. Due to the restricted time frame this phase was not fully executed. Both products that made it this far were constructed and illustrated using 3D models which with modifications can be used when manufacturing hardware.

1.4 Acronyms

Q = Energy/work [J]

m = Mass [kg]

c_p = Specific heat capacity [kJ/kg * K]

ΔT = Temperature difference [°C]

$c_{\text{vaporization}}$ = Vaporisation/condensation energy [kJ/kg]

γ = Surface tension [N/m]

R = Radius [m]

P = Absolute pressure [Pa]

V = Volume [m³]

ΔA = Area difference [m²]

μ = Degree of efficiency

P = Power [W]

σ = Yield strength [Pa]

τ = Ultimate shear strength [Pa]

2 Purpose and aim

The aim of this master thesis was to; by creation and innovation find several innovative milk foamer concepts. The aim was to create concepts that meet customer requirements, are fully feasible to produce, have a reasonable cost and have an appealing design. The main aim was to make at least one fully working prototype.

3 Pre-study

3.1 Barista trends

In the 80s non creamy froth was desirable to different coffee drinks, for example when making a cappuccino the milk and froth was added using a spoon to first block the froth from pouring out of the milk jug, the milk was first added to the espresso and then the froth was scooped on to the espresso. Nowadays creamier and shiny foam is desirable. Baristas today create homogeneous creamy and tasty foam that mixes with the espresso and this makes it possible to create latte art. (Azizian, 2010).

The trend is also that the word foam is used more often than the word froth (Azizian, 2010). This can certainly be explained looking at the meaning of the two words. Foam is a substance that is formed by trapping many gas bubbles in a liquid or solid, a more or less homogeneous substance. The word froth is used when talking about foam on top of liquids.

3.2 Milk foam

3.2.1 Why do milk froth/foam

Milk foam is created when air is led into the milk, the creaminess of the foam is dependent on how the air is led into the milk and it influences the bubble size and therefore the creaminess. The formation of milk foam is mainly possible due to the fact that liquid and air molecules are enriched due to a boundary layer activity and in that way stabilize the boundary layers (Spreer, 1995).

One reason that milk can be foamed is due to the low surface tension of milk (approximately 48mN/m compared to 73mN/m for water at 20°C (Ingelsta, Rönngren, & Sjöberg, 2004), (Kamath, Huppertz, Houlihan, & Deeth, 2008). In conformity soap bubbles can easily be made out of soap-water due to the lowering of surface tension (Weaire & Hutzler, 1999).

The protein in milk helps in the creation of foam, the protein molecules helps trapping the air into bubbles by wrapping itself around it and works as an emulsifier between milk and air. The reason that the protein does this is that one part of the molecule is hydrophobic, and is repelled by water.. Therefore it is looking for anything that is not water to face/bind too. Normally a protein chain is all coiled up with hydrophobic parts facing away from the water solution in which it is dissolved (Hoffmann, 2006).

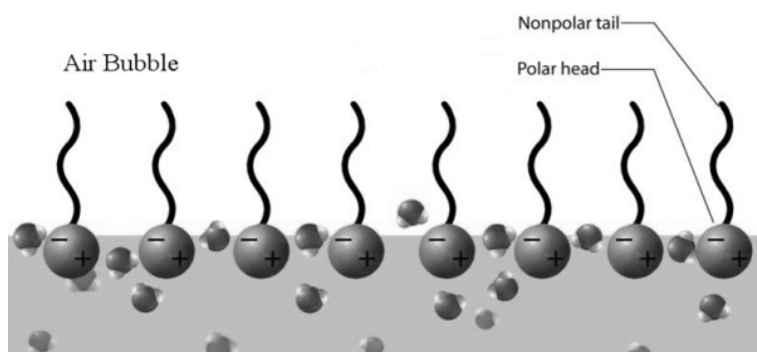


Figure 2: Surfactant molecules lined up on water surface (Hoffmann, 2006)

A surfactant is a surface active agent that can modify the surface tension (Hiemenz & Rajagopalan, 1997). In milk foam one important surfactant is a whey protein, named beta-lactoglobulin (Hoffmann, 2006).

Milk consists of two different types of proteins, whey proteins and caseins. Caseins make up 80% of the total protein of milk, both types of proteins plays an equally important role in the formation of foam. Casein has desirable surface-active properties and thus plays a role in the functional properties of whipping/foaming. Whey proteins offers less surface activity than casein however it have far superior foam stabilizing properties and therefore creating a more rigid film at the air/water interface of the foam. (The Milk Frothing Guide)

3.2.2 What counteract foamability and foam stability

An important reason of failure of the foam is drainage. As gravity pulls the milk between the bubbles, the milk and protein is drained away. This leaves the foam brittle and inelastic causing the bubbles to collapse. Drainage is linked to viscosity, the thicker the liquid the slower the drain. This is why full fat milk is generally easier to work with. It will stay wet longer than skimmed that dries out pretty quick making the foam less creamy (Weaire & Hutzler, 1999).

Fat have one more impact on foam. Fat and water do not mix because water is polar and fat (lipids) non-polar. The part of the protein that is hydrophobic is non-polar, hence is repelled by the water. If fat is introduced into the foam it can give the non-polar part of the protein another choice, it can either wrap around the air bubble or the fat. This is why fat destabilizes foam (Hoffmann, 2006).

If milk will not foam the most likely reason is that the milk fat has broken down and the free glycerol from the tri-glyceride is interrupting the foaming process (Hoffmann, 2006).

Hoffmann (2006) speculate that you get a better more stable foam using a good technique, foam only whilst milk is cool, and then churn/spin up to final temperature (see chapter 3.2.4 for more details in how to produce foam) because you have formed your stable foam before the milk fat has reached body temp. At body temperature the fat turns to oil, and is more likely to mess with the foaming process.

Protein is sensitive to heat, extreme salt concentrations, organic solvents, reducing agents and pH changes. At high temperatures the protein is denatured. Increased thermal motion disturbs the inter-molecular interactions within the protein. (Protein Denaturation) When the milk once have been heated it can be hard to foam a second time (Azizian, 2010).

3.2.3 What is a nice foam/microfoam

When evaluating milk foam/froth, there are some important things to consider. The smaller the bubbles, the better the foam. Nice foam is also viscous and mixes with the coffee, bad foam contains too much air and becomes like a lid on top of the coffee. High quality foam is shiny, tasty and do not contain any big bubbles (Azizian, 2010).



Figure 3: Texture of frothed milk, bad foam (left) and properly frothed milk, microfoam (right)

Nice creamy foam is called microfoam and is a very fine emulsion of denatured milk protein and air which has few or no visible bubbles. Microfoam, in coffee jargon, is a term used to describe an ideal standard for steamed milk, pourable virtually liquid foam that tastes sweet and rich. Proper cappuccinos and lattes require microfoam. Microfoam in the pitcher does not look like foam, since the bubbles are very small. One distinction it has from liquid milk is a soft sheen in the right light (Barista Technique: Frothing Milk).

The qualitative opposite of microfoam is macrofoam, which has visibly large bubbles, a style of milk commonly used for cappuccinos in the 80s (Azizian, 2010). In macrofoam, the foam phase separates from the liquid phase, becomes thick and rises to the surface. If the foam becomes thick, like soft peak beaten egg whites, its taste turns to cardboard, and its appearance in the cup suffers (Hoffmann, 2006).

3.2.4 Some ground rules how to create a high quality foam

Whether using a professional espresso machine with steam pipe, milk foamer or old-fashioned hand-whisker there are some rules to follow when making milk foam. These are some tips to follow to create the highest possible foam using different techniques.

Always use fresh and cold milk ideally 4°C. Never use milk that once has been foamed, it will not be foamed as well a second time because the protein gets denatured when the milk is heated (The Milk Frothing Guide).

If using a whisk, do not whisk too long, then the foam consists of too much air and big bubbles and becomes like a lid over the coffee. Keep whipping just under the surface to make sure that air gets trapped in the milk. It is important to mention that it is difficult to not say impossible to get high quality foam with the milk whisks existing on the market today. This has been proved when testing different milk foamers (see Appendix H: Main tests and Diagram 8: Bubble diameter-Part foam diagram, displaying existing products and [REDACTED]).

When using a professional barista steamer there are three zones distinguished by sound, the sound may vary from machine to machine. In the first zone that is just under the surface, the tip makes a bubbling noise and as it gets slightly deeper, a sucking or tearing noise. In the second intermediate zone, there is very little noise. In third zone near the bottom of the pitcher a loudly roaring noise appear. If using a professional espresso machine with steam pipe place the steam-pipe just under the

surface of the milk so you occasionally hear a sucking/tearing noise, this will drag the air into the milk and create foam. If hearing much of the sucking/tearing noise, the foam will stiffen and not be creamy. The volume of the milk increases, as the liquid turns to foam, this is by baristas called stretching. Keep foaming until the milk has increased about 50% in volume. At this point the side of the pitcher will be lukewarm (40°C, 100°F) (Barista Technique: Frothing Milk).

Time to transition from foaming the milk to simply heating varies depending on machine, nozzle design and amount of milk and of course type of drink the foam is intended to. Using a professional barista steamer the time varies from 3 to 7 seconds, using smaller espresso machines it takes longer. When the foaming is done continue to heat the milk foam by lowering the steam-pipe approximately 2 centimetres under the surface, occasionally hearing a roaring noise (Azizian, 2010). While heating it is of great importance to get the milk in the jug to whirlpool and form a standing wave of turbulence in order to fold foam into liquid. With a one-hole tip, keep it close to the edge of the jug to get rotation of the milk. With a multi-hole tip, point it straight down near the centre of the jug, the hole dispersion pattern on a properly designed tip will create a whirlpool or a standing wave of turbulence (Barista Technique: Frothing Milk). Whatever steam pipe is used it is of great importance to find the right angle to get the milk to rotate. This is a critical point as the bigger bubbles fold down into the milk and collapses, the whirlpool mixing froth with milk result in a smooth consistency. The amount of steam varies from machine to machine and the time spent to heat enough milk for a six ounce cappuccino can go from 10 to 40 seconds.

The milk should ideally not become warmer than 65°C. If it is warmer the taste of the milk starts to change to the worse (Azizian, 2010). The milk is approximately 65°C when it starts to smoke (Skumma mjölk som ett proffs). Milk has approximately the same boiling point as water, but it releases gases at a lower temperature. The best way to make sure that the temperature of the milk does not exceed 65°C is to use a thermometer or learn to determine the temperature by holding your hand under the milk jug. When it gets uncomfortable to hold the hand under the jug the milk is approximately 65°C (Barista Technique: Frothing Milk).

When finished whipping or steaming, knock the jug against a hard surface, this clears the biggest bubbles and the small remains, delicate bubbles makes foam soft and smooth. Swirl the jug in a smooth, circular motion until the mixture of foam and milk becomes homogenous, before adding it to a drink (The Milk Frothing Guide).

If you followed the instruction for steaming with a professional barista steamer the milk will initially be very liquid and will barely mark the surface of the espresso. After approximately 10 to 20 seconds, it will thicken to the correct point where it is suitable for latte art. After approximately 20 to 25 seconds, you can pour something with unclear shapes. Wait too long time and only a simple round foam cap will form (Barista Technique: Frothing Milk).

3.2.5 Different sorts of milk

It is an art to produce good foam and what kind of milk you use plays an important role. For baristas this is a well known fact. The steamed milk helps to highlight the taste of for example coffee latte, tea to hot chocolate. Different types of milk provide various kinds of foam, flavour and texture.

Milk always evolves and fluctuate slightly but constantly in its composition, due to the feed of the cow, the type of cow, the stage of lactation etc. This will result in delicate yet noticeable changes in

the quality of the foam possible to produce. This is especially true with high grade milk that comes from a farm or coop of farms that are suitable for microfoam, as opposite to that big brand name you see on the supermarket shelves (The Milk Frothing Guide).

Foam stability increases with increased percentage of fat, reaching a minimum stability at about 5% fat (whole milk is about 3-4% fat). Foam stability then increases rapidly as fat is increased to 10%, highly stable cream-type foams are possible to form when the fat content is increased above the 10% level (table cream at 18% or whipping creams at 35% etc.) (The Milk Frothing Guide).

Increases in fat content also cause a decrease in foam volume, up to a level of approximately 5% fat. Hence skim milk offers possibility to the greatest volume of foam and most stable foam. This potential decreases gradually from 2% fat milk to whole milk. Whole milk is a little bit more difficult to foam than skim milk. Again if going higher in fat than that 4% whole milk, (beyond a fat content of 5%) results in a steady increase in both foam volume and stability (The Milk Frothing Guide).

If the goal is to create volumes of foam, non-fat milk is what to use. Whole milk are more difficult to foam and work with but in the end massive volumes of foam is not to aim for, satisfying and tasty drink is. The fat in whole milk will make it possible to create microfoam and therefore a tastier drink and in the hands of a skilled barista whole milk will create as much foam as you need (The Milk Frothing Guide).

Arla

This is how Arla describe their different milk products regarding foamability and foam (Råvarorna: mjölken och kaffet). This do strangely enough not coincide with what is generally said about foamability and fom regarding different sorts of milk.

Barista milk/Latte Art milk

Arla's Latte Art milk has a fat content of 2.6% and is enriched with a natural milk protein 3,8% compared to 3,3% in the original Swedish milk with 3,0% fat. The higher protein content combined with a lower fat content makes the milk foam easily.

Standard Milk

Standard Milk reacts quickly to steam and results in creamy, smooth and compact foam that remains long.

Semi-skimmed milk

The milk has a lighter and less rich flavour. It requires more work with the steam-pipe, but can withstand heat for a longer time which allows selecting the thickness of the foam. The foam is also less stable and should be served quickly.

Low fat milk

Low fat milk variants (light and mini) gives a fluffier, but also fugacious foam. It is also difficult to work up the foam the lower the fat content is. Moreover, as this milk has less flavour the coffee taste gets stronger, and therefore it fits better with milder coffee blends for these milk variants.

Strangely this is not what other studies such as (Kamath, Huppertz, Houlihan, & Deeth, 2008) and (The Milk Frothing Guide) get as result when foaming different sorts of milk. According to them the

Semi-skimmed and low fat milk would require less work to foam. This can be due to the many influencing factors that varies in different sorts of milk.

3.2.6 The influence of temperature on foamability and foam

Temperature plays an important role in foamability and foam properties of milk by influencing the conformation of milk proteins. The percentage fat affects the foaming properties of milk and is largely determined by the physical state of milk fat and thereby the temperature at which milk is foamed. Appendix D: Images of foams and Appendix E: Bubble size of foams shows the average values of foamability and foam stability of different sorts of milk (Kamath, Huppertz, Houlihan, & Deeth, 2008).

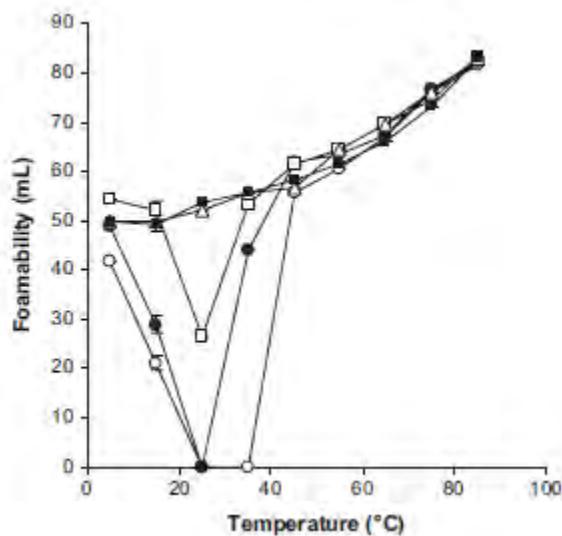


Diagram 1: Foamability of different sorts of milk as a function of temperature (5–85°C): (○) raw whole milk, (●) pasteurized homogenized whole milk, (□) UHT homogenized whole milk, (■) UHT skim milk, (△) pasteurized skim milk. The error bars presented are the pooled standard errors for individual milks. The same standard errors are applied at each data point for a given milk.

UHT treated milk stands for ultra heat treated milk and UHT treated milk will basically stay fresh longer. The foamability of pasteurized and UHT treated skim milk increases gradually with increasing temperature. Milk viscosity decreases with increasing temperature and result in faster drainage and the foam stability is reduced. The foamability of whole milks decreased with increasing temperature up to 25°C (for pasteurized and UHT treated whole milk) or 35°C (for raw whole milk). For all whole milks, foam ability fully recovers at temperatures above 45°C (Kamath, Huppertz, Houlihan, & Deeth, 2008).

The destabilising effect of milk fat on foamability and stability is most obvious when the fat globules contain both solid and liquid fat i.e., in the temperature range 5–35°C, where milk fat globules are most susceptible to partial coalescence; at >40°C, all milk fat is in the liquid form. Therefore differences in foamability between whole and skim milks is noticeable mainly when milk is foamed at a temperature in the range 5–35°C (Kamath, Huppertz, Houlihan, & Deeth, 2008).

The increase in foamability of skim milks or whole milks with increasing temperature in the range 5–85°C or 35–85°C, respectively, is at least partially due to the decrease in viscosity of milk with increasing temperature. The temperature and hence viscosity decrease (more fluid) enabling protein

molecules to migrate more rapidly to the air interface of milk foams (Kamath, Huppertz, Houlihan, & Deeth, 2008).

In (The Milk Frothing Guide) there is a slight different result regarding temperature and foamability, this can be due to different ways of foaming the milk. The Milk Frothing Guide uses a steamer while (Kamath, Huppertz, Houlihan, & Deeth, 2008) uses a sintered glass disk and air pressure to create foam.

According to (The Milk Frothing Guide) low fat milk takes in air more easily at low temperatures. This also applies to both whole milk and cream, although to a lesser extent. So from approximately 4,5°C (40F) (fridge temperature) up to about 38°C (100F), milk foamability are high. However, at approximately 38°C (100F), and up to 70°C (160F) the trend is reversed with the higher fat milk products constantly exhibiting a greater volume (as seen as a percentage increase in volume due to foam) of foam being produced at any given point. Still milk, regardless of fat content, creates the greatest volume of foam at cooler temperatures (The Milk Frothing Guide).

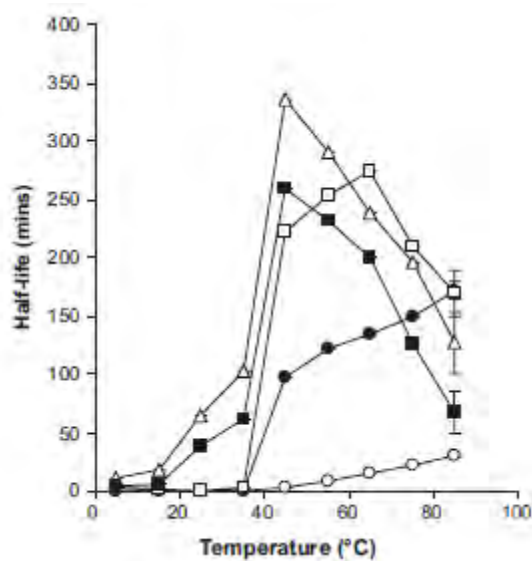


Diagram 2: Foam stability of different sorts of milk as a function of temperature (5–85°C) of milk when foaming: (○) raw whole milk, (●) pasteurized homogenized whole milk, (□) UHT homogenized whole milk, (■) UHT skim milk, (△) pasteurized skim milk. The error bars presented are the pooled standard errors for individual milks. The same standard errors are applied at each data point for a given milk.

Skim milks show a foam stability peak at 45°C. Foams formed by skim milks are in general more stable than foams formed by whole milks, especially at temperatures below 45 °C. At all temperatures studied, foams formed from pasteurized skim milk are more stable than those formed from UHT-treated skim milk. The stability of foam formed from pasteurized or UHT-treated skim milk increases with increasing temperature of foaming up to 45 °C, above which increasingly less-stable foams is formed (Kamath, Huppertz, Houlihan, & Deeth, 2008).

When foaming at 65°C the UHT-treated homogenized whole milk is most stable. Whole milk form particularly unstable foams in the temperature range of 5–35°C and form in general more unstable foam (Kamath, Huppertz, Houlihan, & Deeth, 2008).

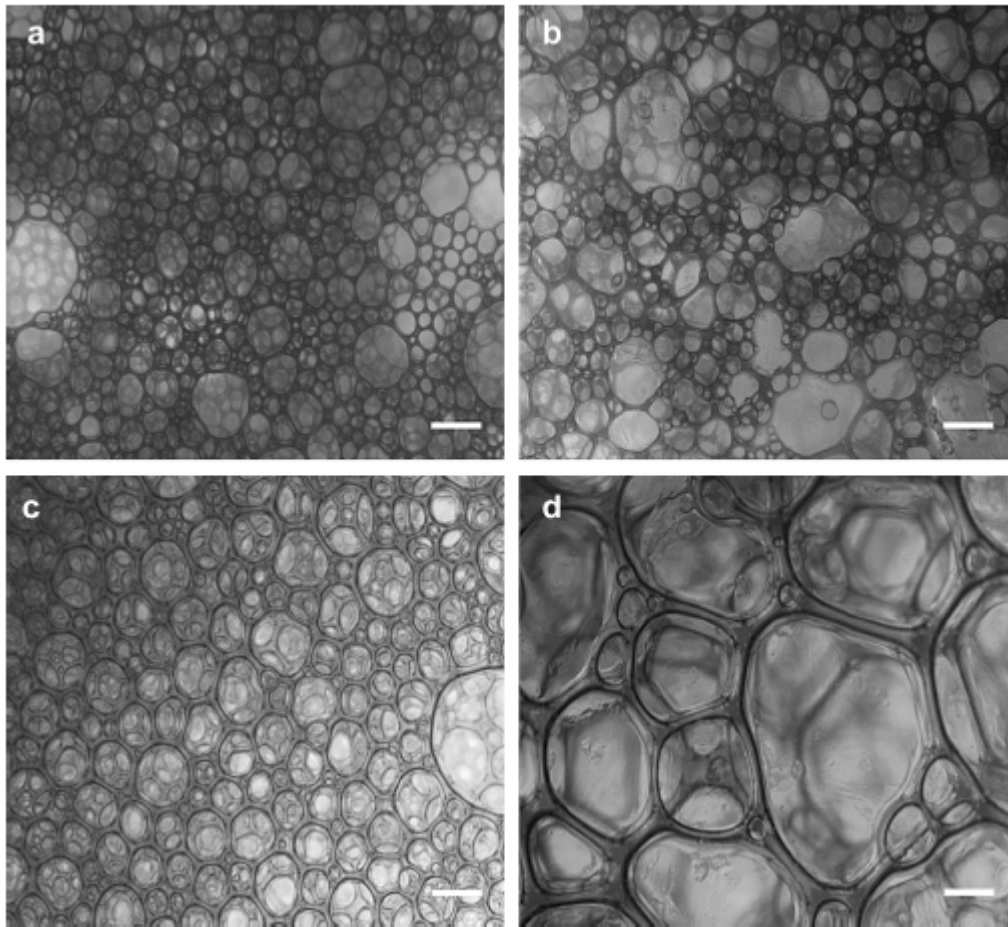


Figure 4: Images of foam formed at 45°C from (a) pasteurized homogenized whole milk immediately after foaming (b) pasteurized homogenized whole milk at half-life (c) pasteurized skim milk immediately after foaming (d) pasteurized skim milk at half-life. Bar =1000 µm.

Half-life, is the time (in minutes) required for the foam to collapse to half its original volume. Appendix D: (Images of foams) show microscopic images of the surface of foams formed from pasteurized homogenized whole milk and pasteurized skim milk at 45, 65 and 85°C, immediately after foam formation and at the half-life of the foams (Kamath, Huppertz, Houlihan, & Deeth, 2008).

Foams that are produced from skim milk and whole milk differ significantly in their appearance and bubble size distributions. Whole milk foams show smaller sized bubbles and higher rates of bubble rupture as a result of coalescence during storage. There is also the same difference in the bubble size distributions of whole milk and skim milk at half-life of the foams. The size distributions in fresh foams are narrower. At the half-life, foam formed from whole milk contains a few large bubbles and a large number of small bubbles (Kamath, Huppertz, Houlihan, & Deeth, 2008).

Appendix E: (Bubble size of foams) show distributions of bubble sizes of foams formed from pasteurized homogenized whole milk and pasteurized skim milk at 45, 65 and 85°C, immediately after foam formation and at the half-life of the foams. The diagrams shows that pasteurized homogenized whole milk get the smallest bubbles when foaming at 45 °C (Kamath, Huppertz, Houlihan, & Deeth, 2008).

3.2.7 Surface tension

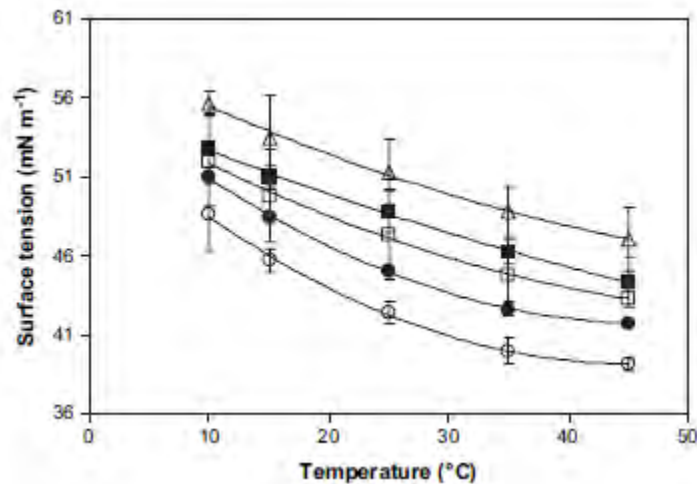


Diagram 3: Surface tension of different sorts of milk as a function of temperature (5–85°C): (○) raw whole milk, (●) pasteurized homogenized whole milk, (□) UHT homogenized whole milk, (■) UHT skim milk, (Δ) pasteurized skim milk. Values are a mean of three determinations using three separate lots of milk.

The transform in the physical state of milk fat over the temperature range of 5–45°C and its obvious effect on the foaming properties of whole milks (see chapter 3.2.6), do not reflect the surface tension values of milk in this temperature range. Surface tension will increase when the foam cool down during storage, resulting in further instability. Furthermore, the surface tension of the milk decreases with increasing temperature and this decrease in surface tension is favourable to improved foamability (Kamath, Huppertz, Houlihan, & Deeth, 2008).

3.3 Physics behind foaming milk

3.3.1 Transmission of energy between steam and milk

The following theory is gained from (Cengel, Turner, & Cimbala, 2008)(Cengel, Turner, & Cimbala, 2008). Consider that no heat losses occurs, in that case the following calculations can be used when determine how much steam is needed to heat a specific amount of milk a certain temperature, in this case 2 dl milk from 10°C to 65°C . Assume that water and milk has the same density 1kg/l.

$$Q_{Milk} = Q_{Steam} + Q_{Vaporization} + Q_{Water}$$

The energy that is needed to heat the milk from 10°C to 65°C is transferred from the steam.

$$Q_{Steam} = m_{steam} * c_{p_{Steam}} * \Delta T_{Steam}$$

$$\Delta T_{Steam} = 0 \quad \Rightarrow \quad Q_{Steam} = 0$$

Considered that the steam is not overheated this energy is equal to zero.

$$Q_{Vaporization} = m_{Water} * c_{Vaporization}$$

$$m_{Water}$$

$$c_{Vaporization} = 2260 \text{ kJ/kg} \quad \Rightarrow \quad Q_{Vaporization} = 2260 * 10^3 * m_{Water}$$

When the water condenses energy is transferred to the milk.

$$Q_{Water} = m_{Water} * c_{p_{Water}} * \Delta T_{Water}$$

$$m_{Water} =$$

$$c_{p_{Water}} = 4.218 \text{ kJ/kg} * \text{K}$$

$$\Delta T_{Water} = 100^{\circ}\text{C} - 65^{\circ}\text{C} = 45^{\circ}\text{C} \quad \Rightarrow \quad Q_{Water} = 4218 * 45 * m_{Water}$$

When the water have condensed and mixed into the milk the temperature of the water will decrease from 100°C to the final temperature of the milk 65°C resulting in energy being transferred to the milk.

$$Q_{Milk} = m_{Milk} * c_{p_{Milk}} * \Delta T_{Milk}$$

$$m_{Milk} = 0.2 \text{ kg}$$

$$c_{p_{Milk}} = 3.77 \text{ kJ/kg} * \text{K}$$

$$\Delta T_{Milk} = 65^{\circ}\text{C} - 10^{\circ}\text{C} = 55^{\circ}\text{C} \quad \Rightarrow \quad Q_{Milk} = 3770 * 0.2 * 55 = 41470 \text{ J}$$

$$Q_{Milk} = Q_{Steam} + Q_{Vaporization} + Q_{Water}$$

$$Q_{Milk} = m_{Water} * c_{Vaporization} + m_{Water} * c_{p_{Water}} * \Delta T_{Water} \quad \Rightarrow$$

$$m_{Water} = \frac{Q_{Milk}}{c_{Vaporization} + c_{p_{Water}} * \Delta T_{Water}}$$

$$m_{Water} = \frac{3770 * 0.2 * 55}{2034 * 10^3 + 4218 * 45} = \frac{41470}{2449810} = 0.0169 \text{ kg}$$

$$V_{Water} \sim 17 \text{ cm}^3 = 17 \text{ ml} = 1.7 \text{ cl}$$

Theoretically 1.7cl water in form of 100°C saturated steam is needed to heat 2dl milk from 10°C to 65°C. A test was made to see if this is likely in practice. 2dl milk was steamed from 10 to 65°C and the mass was measured before and after steaming. The mass had increased with 37g, this indicates that there are some energy losses, for example energy is required to heat the pipe where the steam travels.

3.3.2 Transmission of air into the milk

Existing products at this time transfer air into the milk by the use of steam, whisk or net. The air is forced into the milk.

3.3.3 The physics of bubbles in liquid

This chapter is cited from hyperphysics (Surface Tension and Bubbles).

A bubble can exist because the surface layer of a liquid has a certain surface tension, which causes the layer to behave somewhat like an elastic sheet. However, a bubble made with pure water alone is not stable and a dissolved surfactant is needed to stabilize a bubble.

A bubble in air (see Figure 5) has two spherical surfaces (inside and outside) with a thin layer of liquid in-between, like a balloon. The pressure inside a soap bubble is greater than that on the outside and depends on the surface tension (γ) of the liquid and the radius (R) of the bubble. Imagine that the stationary soap bubble is cut into two halves. When the halves are at rest, each one has no acceleration and hence is in equilibrium. Using Newton's second law of motion, (zero acceleration implies that the net force acting on each half must be zero $\Sigma F = 0$), the expression relating the interior pressure to the surface tension and the radius of the bubble can be calculated.

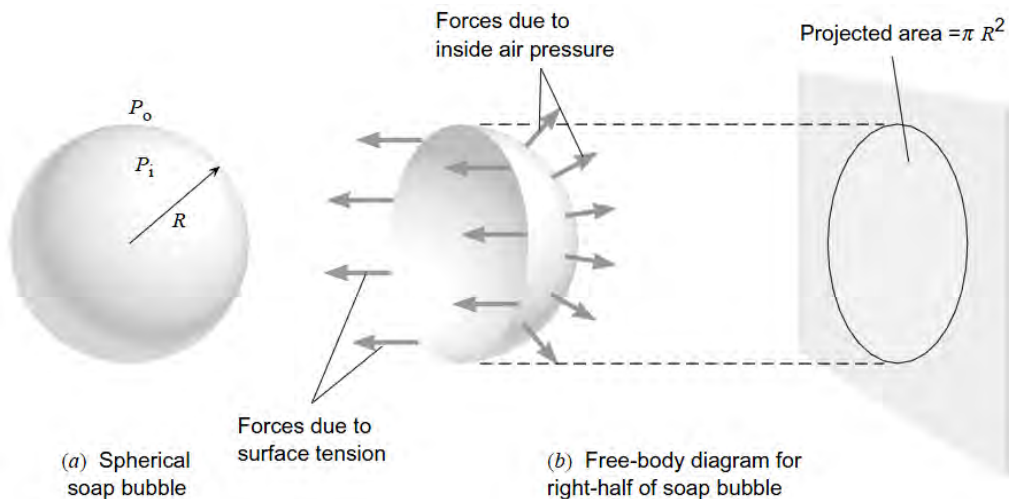


Figure 5: Bubble cut in two halves displaying acting forces.

The product of the surface tension (γ) and the circumference ($2\pi R$) of the circular edge is the magnitude of the force due to each surface ($\gamma 2\pi R$).

Total force due to the inner and outer surfaces is therefore ($\gamma 4\pi R$). The total forces on the surface pointing to the right are equal to the product of the pressure (P_i) inside the bubble times the circular cross-sectional area of the hemisphere ($P_i \pi R^2$). Newton's second law of motion ($\Sigma F = 0$) result in.

$$-\gamma 4\pi R + P_i \pi R^2 = 0$$

This can be written:

$$P_i - P_o = \frac{4\gamma}{R}$$

In general, the pressure P_o outside the bubble is not zero. However, this result still gives the difference between the inside and outside pressures:

$$P_i - P_o = \frac{4\gamma}{R}$$

This equation tells us that the difference in pressure depends both on the surface tension and the radius of the sphere. A greater pressure exists inside a smaller soap bubble (smaller value of R) than inside a larger one.

Spherical drops of liquid or gas (air) bubbles in liquid, like a drop of water or bubble in milk, has only one surface, rather than two surfaces. The force due to the surface tension is therefore only one-half as large as that in a bubble. Subsequently, the pressure difference between the inside and outside of a liquid drop is one-half of that for a soap bubble.

$$P_i - P_o = \frac{2\gamma}{R}$$

To get an idea of what pressures there is inside bubbles in milk foam calculations where done on bubbles with a radius of 0,05mm and 1mm ($\gamma_{milk} = 0,048\text{N/m}$):

$$(P_i - P_o)_{0,005\text{mm}} = \frac{2\gamma}{R} = \frac{2 * 0,048}{0,05 * 10^{-3}} = 1920\text{Pa}$$

$$(P_i - P_o)_{1\text{mm}} = \frac{2\gamma}{R} = \frac{2 * 0,048}{1 * 10^{-3}} = 96\text{Pa}$$

In milk foam the pressure inside a bubble with radius 0,05mm have a pressure of 1920Pa, if the radius is 1mm the pressure is 96Pa.

3.3.4 The physics of foam

This chapter is cited from the book *The Physics of Foams* (Kamath, Huppertz, Houlihan, & Deeth, 2008).

The basic of foam physics is that to create foam the surface area (ΔA) has to be increased and this requires work (Q) (γ is the surface tension).

$$Q = \gamma \Delta A$$

Ideally when microfoam is created a doubling of the volume is made. From 2dl milk 4 dl foam is created, hence 2dl air is captured in the milk. Assume that a microfoam bubble have approximately a radius of 0,05mm. The amount of bubbles can then be calculated.

$$\text{Amount of bubbles} = \frac{V_{air}}{V_{bubbles}} = \frac{0,002}{\frac{4 * \pi * (0,005 * 10^{-3})^3}{3}} \sim 382 * 10^6$$

Then the ΔA can be calculated and also the work:

$$Q = \gamma \Delta A = 0,048 * 382 * 10^6 * 4 * \pi * (0,05 * 10^{-3})^2 = 0,576 \text{Nm}$$

Frothing takes approximately 60 seconds with an ordinary latte whisk, the power (P) required is therefore:

$$P = 0,0096 \text{W}$$

Ordinary latte whisks have a power of 6,9W the degree of efficiency is therefore:

$$\mu = \frac{0,0096}{6,9} = 0,0014$$

The stability of foam is caused by Van der Waals forces between the molecules in the foam, electrical double layers created by dipolar surfactants, and the Marangoni effect.

Several effects can break down the foam. Gravitation pulling down the liquid causes drainage. Osmotic pressure causes drainage within the foam due to internal concentration differences in the foam, and Laplace pressure causes diffusion of gas from small to large bubbles due to pressure difference.

3.4 Existing tests and evaluations of milk foam and milk foamers

3.4.1 International standard

In Appendix F: (International standard) methods for measuring the performance of electric household coffee makers can be viewed. The test is carried out to assess the quality of the frothing process and the stability of the frothed milk relating to bubble size and stability time. Basically the steam function to froth milk is evaluated based on four measurements.

Time to double the volume, measure how long time it takes before the starting volume of milk has been foamed to twice that volume.

Temperature when the volume is doubled, measure temperature when the milk has been foamed

Time to decrease 25% of the doubled volume. Measure how long time it takes for the total volume, when foaming is finished, to decrease 25%.

Mass increase due to steam absorption, measure the mass before and after foaming to determine how much water that has been absorbed from the steam.

Steam function to heat-up water is evaluated based on two measurements.
 The temperature increase of 0.2 litres when steaming for 120 seconds.
 Measure the water absorption of the heated 0.2 litres water.

3.4.2 Lab standard

In Appendix G: (Lab standard) lab standard of milk foam evaluation used by the lab at Electrolux floor care and small appliances AB is presented. It basically suggests to measure:

Time to heat 0.1 litre from 15 to 65deg.
 Mass increase when streaming 30sec.
 Subjective evaluation of the foam, score 1-3.

Characteristics that are evaluated are volume increase related to time, temperature of the foam and size of the bubbles.

3.4.3 Microscopic evaluation

The Bubble size can be measured using a microscope and repeatable treatment of the foaming process and measurement (Weaire & Hutzler, 1999).

3.4.4 Multiple light scattering coupled with vertical scanning

Multiple light scattering coupled with vertical scanning can be used for a more exact measure. It is the most widely used technique to monitor the dispersion state of a product by identifying and quantifying destabilization phenomena. It works on any concentrated dispersions without dilution, including foams. Light is sent through the sample and backscattered by the bubbles. Backscattering intensity is directly proportional to the size and volume fraction of the dispersed phase. Local changes in concentration (drainage, syneresis) and global changes in size (ripening, coalescence) can therefore be detected and monitored (Weaire & Hutzler, 1999).

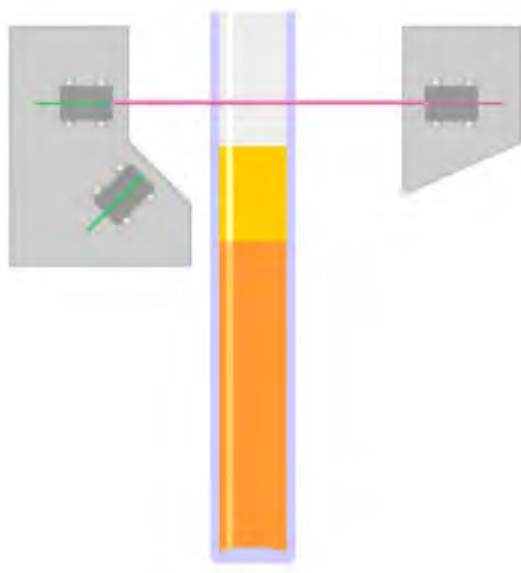


Figure 6: Multiple light scattering coupled with vertical scanning.

3.4.5 MRI

Nuclear magnetic resonance techniques (magnetic resonance imaging) can be used to determine the density of the liquid as a function of vertical position. MRI has been used analyzing egg-white, cream and beer (Weaire & Hutzler, 1999).

3.4.6 Measurement and evaluation of foam and milk foamers

The main characteristics to measure are how creamy the foam is, this is most easily determined by measure the size of the bubbles using a microscope. Smaller bubbles result in creamier foam. The international standard is unsuitable to use because it is difficult to see when the volume has doubled when using a milk foamer with whisks.

One usable part in the international standard test is to measure the volume decrease over time to determine the size of the bubbles. Small bubbles are more stable and large bubbles will collapse fast and therefore less volume decrease on a specified time means smaller bubbles. There is rarely only one variable influencing a result. The relation liquid/foam should have an impact as well, more percentage of foam should increase the rate of volume decrease. Therefore a certain amount of foam has been investigated when determining the volume decrease. This measurement can also be used to see how stable the foam is. As the size of the bubbles is determined using a microscope this measurement would primarily be used to get an idea of the size of the bubbles. It has been showed that over a time of 30 minutes the decrees in foam volume is very small and therefore this measurement will not be used hence cappuccino or latte will be finished in that time.

There is often some unformed milk left on the bottom of the jug when one have foamed milk. The aim is to get a homogenous foam and therefore there should be no unformed milk left on the bottom of the jug, this is however difficult to obtain. The percentage of liquid and foam compared to the whole volume will be measured to determine quality of the foam, higher percentage of foam indicate high quality foam in terms of homogeneity.

Subjective evaluation of the foam with score 1-5 will be used, 1 for a poor result and 5 for an excellent result. After all in the end this is how the customers evaluate foam (Kaveh Azizian). Due to price the apparatus for scattering measurement or MRI will not be used.

3.5 Modified tests and evaluations of milk foam and milk foamers

To suite this particular kind of project some modified tests and evaluations gathered from existing tests above will be used. Tests and evaluations will be performed to understand which existing solutions that meet customer requirements and they will later be used to evaluate concepts and prototypes.

Objective tests

1. Time to foam
2. Temperature on the froth/milk [°C]
3. Increase in volume [%]
4. Part foam [%]
5. The size of the bubbles using microscope, diameter [mm]

The same amount (1dl) and kind of milk (Arla whole milk 3% fat) is used in every test, exactly the same procedures are repeated for every test. The time it takes to foam milk is measured, for devices that do not heat milk time is measured from starting to foam the pre heated milk to when a satisfying amount of foam is obtained. Those devices that also heat the milk time is measured from when the

milk is inside the container and the start button is pushed to when the advice automatically turns off. When 1 dl milk is foamed temperature of the foam is measured, then the foam is poured into another jug and the volume is measured. Then the jug is knocked 4 times and swirled 5 times. A cup is filled with only foam and a camera-photo is taken and also microscope photos with zoom 1, 2, 4 and 8. To determine the mean diameter of the bubbles one small part of the foam is investigated 5 different diameters are measured and a medium diameter is obtained. This measurement is not that exact and should be used to get an approximate measure on the mean diameter of the foam bubbles. These tests are performed to see that critical values are obtained (milk temperature that not exceeds 65 °C) and they will also help setting the subjective rankings on the foam and milk foamer.

Subjective evaluation of foam

6. Shine (shiny) photo [1-5]
7. Taste and texture [1-5]
8. How well it mixes with the coffee/satisfying viscosity [1-5]

These characteristics measure foam quality and are a subjective evaluation ranked 1-5. When the objective tests are done the shine is evaluated. Then a taste of the foam is performed to evaluate taste and texture. With some training the delicate taste in the mouth can be used to determine texture. The sparkling sound that the foam emits when the bubbles breaks is a characteristic that helps determine the bubble size and creaminess. The mouth can be used to determine the size of the bubbles, the more sound the foam emits when squeezing it against the palate the bigger the bubbles. High quality creamy foam emits almost no sound at all. The milk is also poured into a cup of coffee to see how well the foam mixes with the coffee.

Subjective evaluation of milk foamer

9. User friendly [1-5]
10. Easy to clean [1-5]
11. Handling [1-5]

Product characteristic are evaluated from 1-5 to determine how user friendly they are. User friendly involves how easy it is to get high quality foam without being very skilled at using the product. If it requires a lot of practise to form quality foam with the product, it scores a 1, if it does not require practice it scores 5. As seen in chapter 3.8.1 (General survey) one important customer requirement is how easy the product is to clean therefore it is ranked from 1-5 with 5 being a the most positive score. Some of the products on the market need a lot of handling and requires even pre-heating of the milk. Little handling of the product free time that can be used to prepare coffee, this can be desirable, if the product need a lot of handling it scores 1 and if it needs little handling it scores 5.

Scores

12. Foam
13. Use
14. Total

From the subjective tests three different scores are obtained. Foam quality score simple is a sum of the three rankings that comes from the subjective evaluation of the foam. Use, is a sum of the three subjective evaluation of milk foamer. Total score is a sum of all the scores multiplied with the percentage of foam, volume foam compared to total volume.

In this way products that create high quality foam and those who are easy to use can be identified. The total score helps identifying products that has a high overall score. This can be useful to see when evaluating concepts and prototypes since focus can have been lying on different customer

requirements, for example user friendly or creating high quality foam. To see charts of test results go to Table 1: (Evaluation of different milk foamers), Table 8: (Evaluation of prototypes) and Appendix H: (Main tests).

3.6 Market analyse

Early in the project benchmarking took place to get a picture of what exist on the market. What functions and products do other brands use to foam milk. These are the existing solutions on the market today (2010-03-08). How user friendly the products are vary a lot and different way of foaming milk result in different grades of foam quality. Go to (Appendix H: Main tests) to se resulting foam quality and how user friendly these products are.



Figure 1: OBH Nordica Café crema

General small latte whisks

General small whisks are powered by batteries, the batteries run an electric motor that is directly connected to a whisk. Whisk is used in preheated or cold milk. (OBH Nordica Café crema). Some differences on handle and whisk exist but the main technique is the same. For example Bodum Mousse Battery Operated Turbo Milk foamer has a patented blender spiral attached to the rod, this can be adjusted according to the amount of milk that needs frothing. Motor and batteries are placed in the head which fits in to the jug the milk fomer comes with. These products are easy to use and clean but require handling as they do not heat the milk. The general small whisk creates a big volume of non creamy froth, too much air and big bubbles are absorbed in the milk. There is a complete lack of creaminess. If the whisk is held against the wall of the jug to decrease the speed slightly better foam is produced.

Electric whisk milk foamers

Milk is poured in a jug, the bottom of jug consists of a heat block and heats the milk, in the same time the milk is whisked using a small whisk rotated by a magnetic force or direct connection to a motor. Product comes with different functions, OBH Nordica Latte Pronto can only create warm foam while Nespresso Aeroccino can create both cool and warm foam. Both can be used to only heat the milk as well. Froth au lait is another milk foamer in this category, the only different is that it has a rotating net instead of a whisk. These products are generally easy to use and clean and requires little handling. Electric whisk milk foamers also create a big volume of non creamy foam but a total lack of creaminess. Slower whisk speed creates a slightly more creamy froth with smaller bubbles.



Figure 2: Nespresso Aeroccino



Figure 3: Bialetti Tutto Crema

Cups with squeeze net

Milk is heated in the microwave oven or on a stovetop plate in the jug and then the milk is squeezed through a filter several times. This makes the milk foam. Some have two nets ni a row like Bialetti Tutto Crema others have just one net. Most of them come with a jug but Pressocanada Milk foamer can be placed in any small jug. Cups with squeeze net create most creamy foam of the existing standalone

products on the market. Depending on design some can produce microfoam, still others can result in worse quality foam with bigger bubbles and less creaminess. The foam depends on the type of net and how well sealed it is against the jug. A finer mesh and better sealing result in better quality on the foam.

Stovetop milk steamer

Stovetop milk steamer consists of container, handle, safety release valve and adjustable valve. Water is placed in the container, the container is sealed and placed on the stovetop. High temperature steam is produced, when the steam starts to shoot out the safety valve the steamer is ready to use. The pipe is placed into the milk and steam is released into the milk which froths and heats the milk. This product requires some practise to get a nice foam. To form a nice foam the same instructions as presented in chapter: 3.2.4 (Some ground rules how to create a high quality foam) can be followed. It is easy to get burned at this container as it mostly made of stainless steel which has a temperature of approximately 140°C when steaming. This solution is similar to the one generally used in espresso machines. The pressure in the stovetop container can reach 3,5bar while pressure in espresso machine tanks is (2-5), 2bar in Electrolux Cremapresso & Electrolux Easypress. Se Chapter 8. (Discussion) on a suggestion why the pressure in the tank plays an important role in how the quality of foam will end up.



Figure 4: Stovetop steamer

Steam milk foamers

Milk froth is produced by using steam, high temperature steam is produced in a boiler or a chamber with a thermo block. Steam is let out through a nozzle, in the nozzle there is a small exit connected to a milk container. Due to the high flow of steam low pressure is created near the exit connected to the milk container, milk will therefore be forced into the nozzle and blends with the steam creating hot foam. There are a lot of different patents on this solution. AEG Crema Classica and AEG Electrolux Caffé Grande are some of the products using this kind of technique. In the case of AEG Crema Classica the boiler have to empty when finished foaming so the machine have to be turned off approximately 8 seconds in advanced the foam volume is satisfying hence steam will go for 8 seconds after turning it off. The steam flow is high and it often gets very messy around the machine hence the milk is splashing. Set to create latte foam, steam milk foamers can create satisfying foam, if it is set to create cappuccino foam, less creamy foam are produced. This technique so far cannot produce microfoam and generally there is a great volume of milk that comes out the pipe unfrothed. Also the foam exceeds 65°C.



Figure 5: AEG Crema Classica

Espresso machines with steam pipe

High temperature steam is created in a boiler or a chamber and thermo block. Steam is led through a pipe with a nozzle and then released into the milk. Used correctly with the right technique steamers that exist on professional barista espresso machines give satisfying microfoam. To read about the technique go to chapter 3.2.4 (Some ground rules how to create a high quality foam). Steamer on commercial espresso machines can give a satisfying result if used properly but there is a need of training and still the result will not be as good as with a professional steamer. This is due to different levels of pressure in those two machines, further discussions regarding this is found in chapter 8. (Discussion).



Figure 6: Easypresso

Lavazza Mio Amado cappuccinatore

Lavazza Mio Amado cappuccinatore is the only product using this combined technique. This advise have to be used with an espresso machine that have a steam pipe preferable Lavazza Mio Amado. Steam from the steam pipe is led into the jug of milk trough a pipe without a nozzle and in the same time a whisk rotates in the milk run by a directly connected motor. This advice is not easy to use, it have to be connected to a wall socket and the steam pipe. The whisk has to be turned on at the same time as the steam and in the end there are a lot of parts to clean. The foam quality is neither that satisfying. Steam and whisk give almost the same result as if only using the whisk, the result is non creamy foam with big bubbles.



Figure 7: Lavazza Cappuccinatore

Table 1: Evaluation of different milk foamers

	Objective					Subjective							Sum		
	1	2	3	4	5	6	7	8	9	10	11		12	13	14
	Time [s]	Temp [°C]	Volume [times]	Part [%]	Diameter [mm]	Shine [1-5]	Taste/ [1-5]	Viscosity [1-5]	Use [1-5]	Clean [1-5]	Handling [1-5]		Foam	Use	Total
Products on market															
AEG Crema Classica	36	63	2	75	0.125	1	1	1	3	1	1		3	5	6
Nespresso Aeroccino	48	68.5	3	83	0.215	1	1	1	5	5	5		3	15	15
Lavazza cappuccinatore	69	65	2.9	83	0.137	2	2	2	3	1	1		6	5	9
AEG Caffé Grande (Cappuccino)	55	70	2.1	50	0.198	1	1	2	4	2	3		4	9	7
AEG Caffé Grande (Latte)	55	69	1.75	40	0.136	3	1	5	4	2	3		9	9	7
Electrolux Easypresso	66	65	2.2	80	0.238	1	1	2	1	5	2		4	8	10
Stove top milk frother	67	65	2.5	80	0.134	1	1	1	1	5	1		3	7	8
OBH Nordica cafe' crema	60	65	2.1	62	0.172	1	1	1	3	5	1		3	9	7
Bialetti	30	65	2.3	90	0.116	3	3	5	4	2	1		11	7	16
Bodum press	30	65	2	90	0.073	4	4	5	4	2	1		13	7	18

3.7 Patent scan

In order to find innovations and patents regarding milk foamers a patent search was made using the online service esp@cenet developed by The European Patent Office (EPO) (esp@cenet, 2010)(esp@cenet, 2010).

Searches were mainly done in the class: A47J (A:Human necessities/47:Furniture/J:Kitchen equipment) and the subclasses:

A47J27: Cooking-vessels

A47J31: Apparatus for making beverages

A47J36: Parts, details or accessories of cooking- vessels

A47J43: Miscellaneous implements for preparing or holding food

A47J44: Multi-purpose machines for preparing food

Search words that was used included : milk foam, milk froth, milk foamer, milk milk foamer.

Many patents exist in the area of milk foaming, on almost every type of commercial milk foamer some patent could be found. As a result of the wide variety of patents the patents will be more thoroughly investigated when noticing that a product idea or concept is heading in the direction of an existing patent. To see some images and abstracts of different patents that was found go to Appendix I: (Patent scan).

3.8 Customer research

As Electrolux did not have any customer researches regarding this particular project, a rough customer research was done including two surveys. This was done to get a rough picture of what the customer think about milk foamers. The surveys were sent out to the students at the program Master of Science in Mechanical Engineering at Linköpings Tekniska Högskola.

3.8.1 General survey

A general survey (Appendix J: General survey) (<http://www.surveymonkey.com/s/KBZYF7W>) was sent out to get an idea of what people think about milk foamers. 48 (35 male and 13 female) Swedish people in the ages 20-35 participated. Of course the amount of people that responded by compiling the survey was not large enough to make general assumptions but it gives a rough picture of what to consider in the making of concepts. A compilation of the most useful information that was gained is presented in Diagram 4: Customer requirements, to see the complete compilation of all the answers go to Appendix K: (General survey answers).

Most (60%) of the participating people do not have milk in their coffee mainly because they do not like it. Some other reasons were that they did not have a milk milk foamer or that it takes to long time to prepare milk foam. The answers clearly show that most of the participants like creamy foam and not the foam that becomes like a lid on the coffee. Most often people use milk with 1,5% fat (medium-fat milk) or Milk with 3,0% fat (high-fat milk). Some of the participants mentioned that they would like to be able to make milk foam at home with the same kind of quality as in a café. Other ideas were that it should be possible to wash the milk foamer in the dishwasher and that it should not be space consuming.

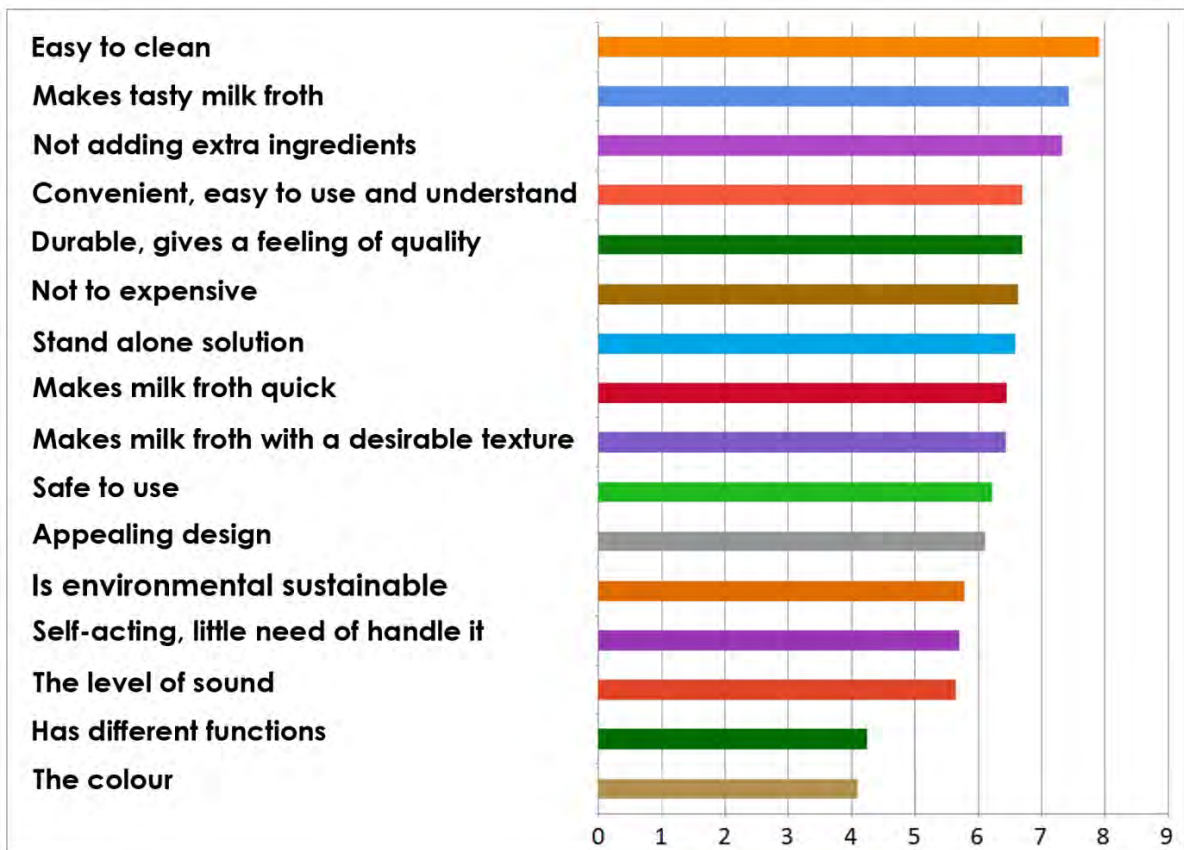


Diagram 4: Customer requirements, x-axis displaying percent

Out of 47 answers the four most important requirements are:

- Easy to clean
- Makes tasty milk froth
- Makes natural milk froth without adding extra ingredients
- Convenient, easy to use and understand

3.8.2 Kano survey

A Kano survey (Appendix L: Kano survey) (<http://www.surveymonkey.com/s/FLBJ22C>) was sent out to get an idea of what people think about different milk foamer characteristics, are the characteristics necessary, attractive, one-dimensional, indifferent or reversed (Kano & Nobuhiku Seraku, 1984)(Kano & Nobuhiku Seraku, 1984). 24 Swedish people in the ages 15-35 participated.

The Kano questionnaire is useful to get a deeper knowledge about the characteristics of the more important attributes that were found from the first general survey. With this method it is easier to understand what the product should include and what is not necessary. This information is really important because it comes directly from the customers and is strictly correlated to the future customer satisfaction. A compilation of useful information that was gained is presented in Diagram 5 Kano better-worse diagram, to see more thorough analyse of the answers go to Appendix N: (Kano diagrams). To see the complete compilation of all the answers go to Appendix M: (Kano survey answers).

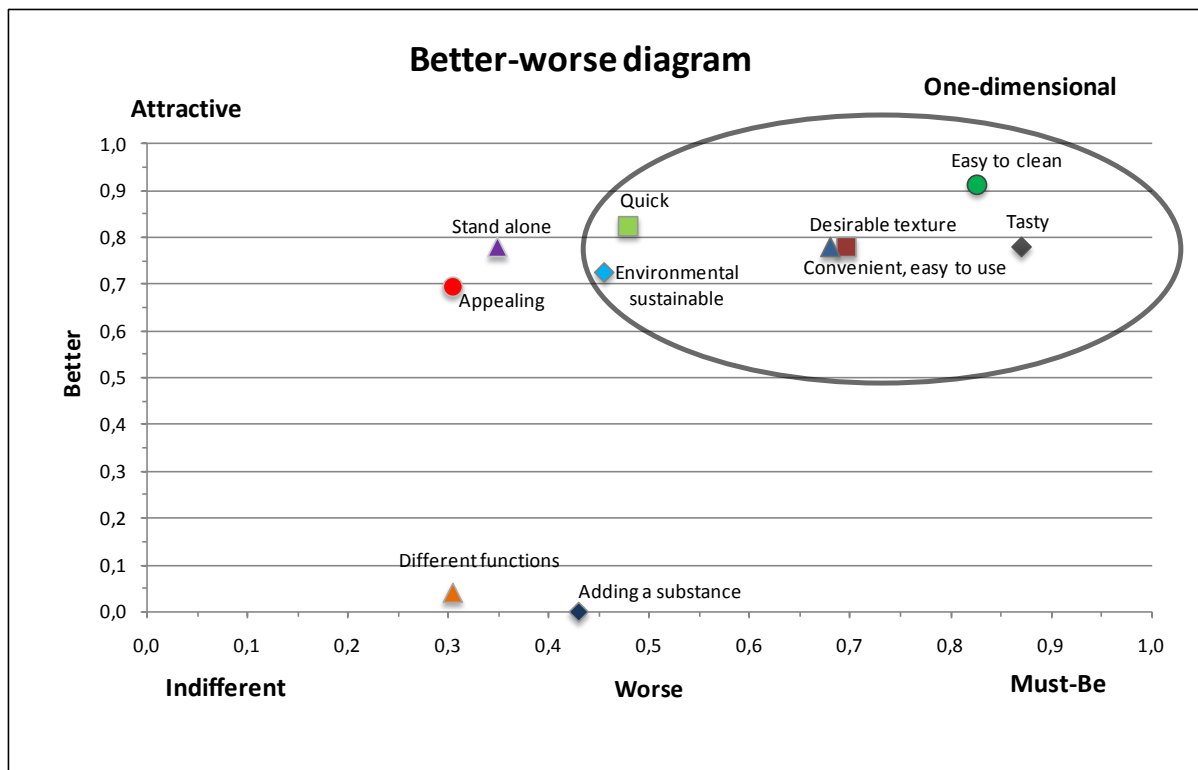


Diagram 5: Kano better-worse diagram to see the complete compilation of all the answers go to Appendix M: (Kano survey answers). To see detailed diagrams of analysed result see Appendix N: (Kano diagrams).

As shown in Diagram 5 there are no must-be characteristics that needs to be included in the product in order to maintain customer satisfaction. The one-dimensional characteristics are easy to clean, convenient, desirable texture and tasty foam. If one-dimensional characteristics are fulfilled in a high level the customer satisfaction will most likely be high. The fulfilment of one-dimensional characteristics is linear proportional to customer satisfaction. If the attractive characteristics; standalone and appealing will be fulfilled the customers will be satisfied in a higher level. If the attractive characteristics are missing in the final product the customer will not be unsatisfied but if they are included the customer will be satisfied in a high level. The characteristic, different functions are indifferent and therefore the customer will not be more or less satisfied if this characteristic is included or not. As shown in Appendix N: (Kano diagrams) the characteristic, adding a substance is reversed and this characteristic will therefore not be included in the final product. If it would be included the customer satisfaction would be decreased.

4 Creation of ideas

4.1 Brainstorming meeting

A brainstorming meeting took place at the Electolux Floor Care and Small Appliances AB Primary Development Lab 2010-02-25. The meeting was led by Stefan Axelsson and the participants were project managers Henrik Eriksson, Stefan Jonsson and Fredrik Sjöberg.

The main problem to solve was how to create milk foam, secondary problem was how to heat the milk. No criticism was allowed and the aim was to get as much ideas as possible.

The brainstorming session started with the “As easy as if” exercise. Each participant came up with at least three ideas each and then the ideas were discussed and developed by the group.

4.2 Ideas and evaluation

The following ideas have been generated; rough tests were made to determine if the different ideas actually work. Rough evaluations were made to determine which ideas to bring to the next phase. Ideas are divided into three categories; integrated solutions in espresso machines, milk foamers that cooperates with espresso machines and Standalone solutions. Some of the ideas can be used in several categories but they are presented in the category that they are most likely to be used. Many of the unfeasible ideas are documented as well so that the same mistakes do not have to be repeated.

4.2.1 Integrated concepts

1. Fine air nozzle, which creates small bubbles

The idea was to release compressed air or compressed hot air into the milk to create foam and at the same time heat it. To determine if it is possible to use hot air to froth milk, tests and calculations were done. Hot air was led into a sealed container of milk to determine if all the energy from the air is transferred into the milk, the input and output temperature was measured. The result showed that the outgoing temperature was the same as the milk therefore it is determined that all of the thermal energy of the air (above milk temperature) is transferred to the milk.



Figure 8: Different nozzles

The following equations can be used.

First the amount of energy to be added to the milk is calculated.

$$Q_{Milk} = m_{Milk} * c_{pMilk} * \Delta T_{Milk}$$

$$m_{Milk} = 0,2kg$$

$$c_{pMilk} = 3,77kJ/kg * K$$

$$\Delta T_{Milk} = 65^{\circ}C - 10^{\circ}C = 55^{\circ}C$$

$$\Rightarrow Q_{Milk} = 3770 * 0,2 * 55 = 41470J$$

Then the volume of air that has to be transferred into the milk to add that amount of energy is calculated.

$$Q_{Air} = m_{Air} * c_{p_{Air}} * \Delta T_{Air} = V * \rho_{Air} * c_{p_{Air}} * \Delta T_{Air}$$

$$\rho_{Air} = 1,2\text{kg/m}^3$$

$$c_{p_{Air}} = 1,00\text{kJ/kg} * \text{K}$$

$$\Delta T_{Air} = 500^{\circ}\text{C} - 65^{\circ}\text{C} = 435^{\circ}\text{C}$$

$$Q_{Air} = Q_{Milk} \Rightarrow$$

$$V = \frac{Q_{Milk}}{\rho_{Air} * c_{p_{Air}} * \Delta T_{Air}} = \frac{41470}{1,2 * 1 * 10^3 * 435} = 0,0760\text{m}^3 = 76\text{dm}^3$$

If only using air to heat the milk the necessary volume would be approximately 76l. The effect would be too low and therefore using this method for heating the milk is rejected.

Disregarding from heating, different nozzles have been tested to see if air can be used to froth milk. For example a bigger net outside a fin net, to collapse the bigger bubbles. All the different nozzles gave approximately the same result, way too large bubbles. Conclusions made from the tests are that it does not matter how fine the filter of the nozzle is, the bubbles will anyway coalesce when released from the mesh resulting in big bubbles. Due to surface tension the bubbles created near the filter will also stay at the filter until they have grown big enough to release.

2. Nozzle that makes the milk rotate

The nozzle would be designed to create a rotation in the jug to drag down bubbles in the milk and make the big bubbles collapse. Steam would be used to both heat and froth the milk. This could be useful for those who not know how to foam milk with a steam nozzle, although a correctly pointed original steam nozzle creates as much flow and gives the same result. Tests also show that the steam flow is too low to create a stable flow using more than one steam exit hole. The steam flow does not create enough flow in the milk to drag down a desirable amount of foam.



Figure 9: Nozzle that makes the milk rotate

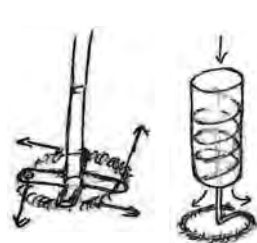


Figure 10: Whisk run by steam

3. Whisk run by the steam / Nozzle that rotates

The nozzle could be designed so that the nozzle starts to rotate and work as a whisk and the steam is led into the milk to heat it. As above solution the holes and steam flow would be pointing tangential to the whisk circle and the nozzle can freely rotate around its axis. The rotation creates a swirl that drags down bubbles so that the big bubbles collapse. To run this whisk a higher steam flow is needed.

4. Friction foamer

Two plates creating foam and heat by friction. The idea is to lead the milk trough two plates that oscillate. Tests were made with different materials and surfaces, tests showed that the concept do not produce enough foam or heat.

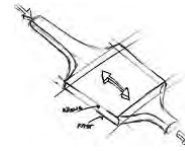


Figure 11:
Friction foamer

5. Use ultrasound to rupture the biggest bubbles

Test showed that ultrasound cannot be used for creating milk foam. Another idea was to rupture bigger bubbles by using ultrasound. Henrik Eriksson at Electolux Floor Care and Small appliances AB has good knowledge of ultrasound and was sceptic about this idea. As figured the ultrasound do not travel that good in foam and rupture of bubbles was not noticed. Test was made to see if concept 1. Fine air nozzle, which creates small bubbles could work in milk exposed to ultrasound, unfortunately this was not the case.

6. Carbonic acid milk foamer

By using a Soda streamer this idea could easily be tested. The test showed that it is hard to control the foaming process, also the froth is not stable and quickly disappears. Also the milk gets a sour flavour that is not suitable to blend with coffee.

7. Higher pressure and bigger tank

A higher pressure and bigger tank would make it possible to create microfoam with a steam nozzle. Higher pressure and bigger tank creates a more powerful and stable steam flow that is necessary when creating microfoam using steam. It would also be possible to redesign the nozzle to create the best flow in the milk. However this is not within the scope of the project, the tank size and the tanks resistant to pressure can easily be changed in the product development. Hence some components have to be made more powerful it is a question of cost and size of the machine.

4.2.2 Cooperating concepts

8. Whisky glass bottom milk jug

The idea emerged looking at a non flat bottom whisky glass. Unfortunately it would not be a useful application to milk jugs hence the centre of gravitation is higher above the bottom the jug could easily tip. With the right design it can create a little swirl but it will not be effective enough and it is easier to just swirl the jug by hand.

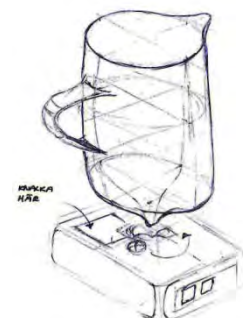


Figure 12: Jug with a non flat bottom

9. Something that knock the milk jug to reduce the big bubbles

The jug have to be knocked from underneath to brake the big bubbles. A quite big knock is needed and the idea is simply not effective enough and it is easy to do by hand, just knock the jug against the table.

10. Steamer application

This concept consists of the same solution as in AEG Crema Classica. The idea was that the tip of the construction can be placed at the steam nozzle on any espresso machine and create the same froth as AEG Crema Classica. This can be handy when foaming bigger volumes. This solution can be less convenient to use if the steam nozzle on the espresso machine is close to the bottom of the machine. This will result in the extra nozzle getting too close to the table and no cup will fit under the nozzle. Also the milk can have trouble travel to the nozzle, hence to long tube and to weak steam flow. The steam nozzles on Electrolux espresso machines are not standardised so this product has to be redesign to fit every espresso machine.



Figure 13: Steamer application

4.2.3 Standalone concepts

11. Induction heated whisk

The idea was to use induction to heat a whisk that can be put in any cup, advantageously the one you are going to drink your coffee from. There is a magnetic stirrer in the induction plate that makes the whisk rotate resulting in the whisk being the only thing that needs to be cleaned. Simplified the whisk will be heated and rotated in the same time. The whisk-ball could be attached to a rope that can be hung over the edge of the cup. The rope could be attached to the edge with a clamp or the whisk-ball could have a

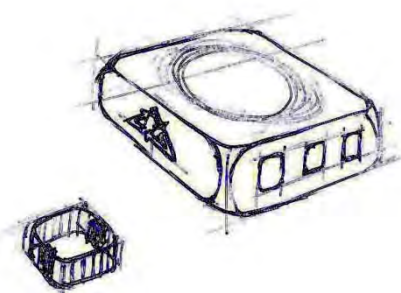


Figure 14: Induction heated whisk

magnetic spot and come with a magnetic rod. If using the same size of whisk and Induction plate, the system can calculate the heat of the whisk (Martin Andersson Electrolux Floor Care and Small Appliances AB). A function that turns off the induction plate when the milk is 65°C could be constructed. Test was carried out using an induction stovetop, a cup and a metal plate to see if it is feasible to use induction to heat a whisk. The 2.5mm thick and 50mm diameter steel plate did heat 2 dl milk in 13 minutes, the result was roughly the same with or without something that whisked the milk. The effect decreases by the square of the distance from the induction coil and therefore not enough heat is produced in the whisk. Milk will not be heated in a desirable amount of time when using a cup with approximately 1 cm thick bottom. The induction effect also decreases with the area of metal in the pot, in this case a whisk. The whisk has to be small to fit in a cup and the effect will be insufficient. The coils could be designed to fit a cup but the effect would probably still be too small.

An Induction stovetop plate with a diameter of 0.2m has a power of 3000W, this result in a power per square meter of 95 kW/m². When heating 2dl milk in one minute approximately 600W is required. If 600W would be maintained in a 0.05m circular plate the power per square meter would be 849kW/m². Nespresso Aeroccino have an power per square meter of 105 kW/m² and this sometimes result is slightly burned milk in the bottom of the jug. The whisk would have to be designed with flanges so that the total area would be at least approximately 0,006m².



Figure 15: Ball loaded with steam

12. Ball loaded with high pressure steam

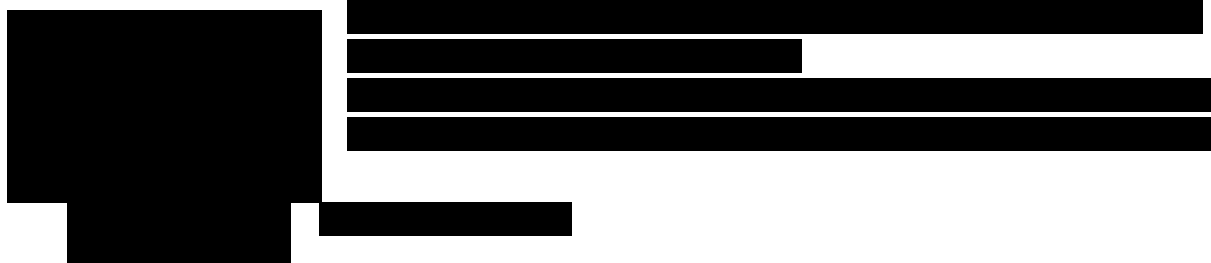
Pour water in the ball and then use an induction, gas or ordinary stovetop or microwave oven to heat the ball. The water inside the ball will boil and pressure builds up. When the pressure is high the ball is released in the milk and steam is let out into the milk. The ball could be attached to a rope and put to the edge of the cup with a clamp or the ball could have a magnetic spot and come with a magnetic rod. Looking at temperature-entropy diagram with pressure and specific volume curves it is unfortunately easy to realise that the ball has to be big to contain enough energy to be able to heat 2dl milk.

13. Shaker

Create foam by shaking a special designed container with milk. A net was placed inside a bottle to test if the idea is feasible. Milk was added and then the milk was heated in a microwave oven, the bottle was then shaken rapidly. It resulted in formation of foam but the quality was poor. If using a mesh with big holes the created foam consists of too big bubbles, if the mesh is too fine the milk will not penetrate the mesh just by shaking. Test was also performed with a heavy net that moves by shaking the flask. Unfortunately the net will not travel a desirable distance in the milk.



Figure 16: Shaker prototype



15. Air sling whisk

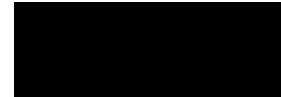
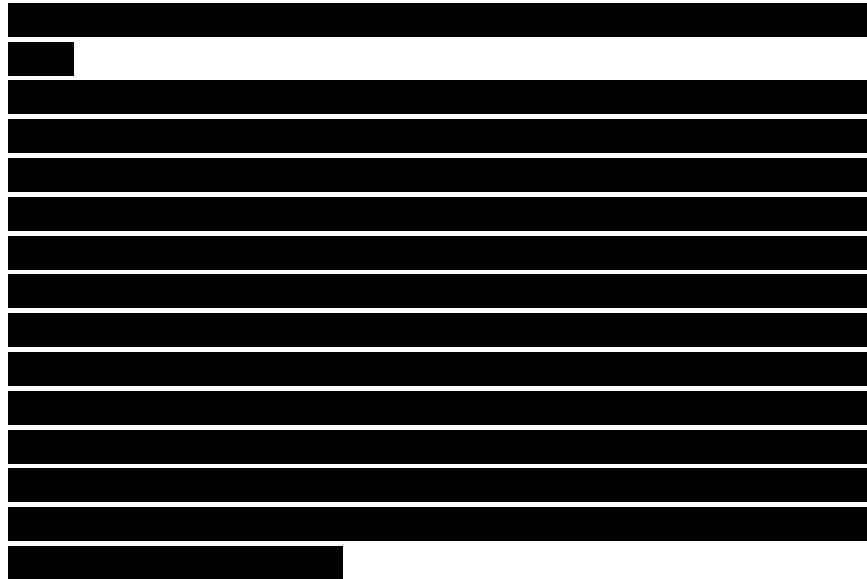
This device looks like an ordinary milk whisk except that the head of the whisk consist of two circular plates and a pipe instead of an ordinary milk whisk. The two plates are placed with a small distance between each other. In the upper plate there is a hole in the centre and a small pipe attached as an elongation of the hole. The air is sucked down the pipe and forced out between the two plates due to the centrifugal force. The air sling whisk works but the air bubbles that are created are too big.



Figure 17: Air sling whisk prototype

16. Coil running a whisk in microwave oven

The idea was to heat milk in microwave oven and at the same time froth the milk with a whisk. No technology that can absorb this high frequent energy has been found therefore this concept is rejected.



18. Use milk to foam milk

Using milk to foam milk means that the milk is used as medium which creates the foam. The milk brings air into the milk when it is sprayed into the milk. To see if this is a feasible solution a pump that is used to spray washer fluid on car windscreen is used to building a rough prototype. Following are tests used for evaluating some ideas regarding foaming milk with milk.

Test 1: This test was done with cool milk and no heating was involved. Milk was pumped from a jug through the pump and then back into the milk trough a narrow nozzle, the same nozzles as used in Electrolux Cremapresso steamer. Nice creamy foam is created When spraying milk into milk with the nozzle placed just at the surface. If the nozzle is placed under the milk surface a satisfying amount of milk foam is not created. Too large bubbles are produced with the nozzle placed above the milk surface.



Figure 18: Prototype that uses milk to foam milk

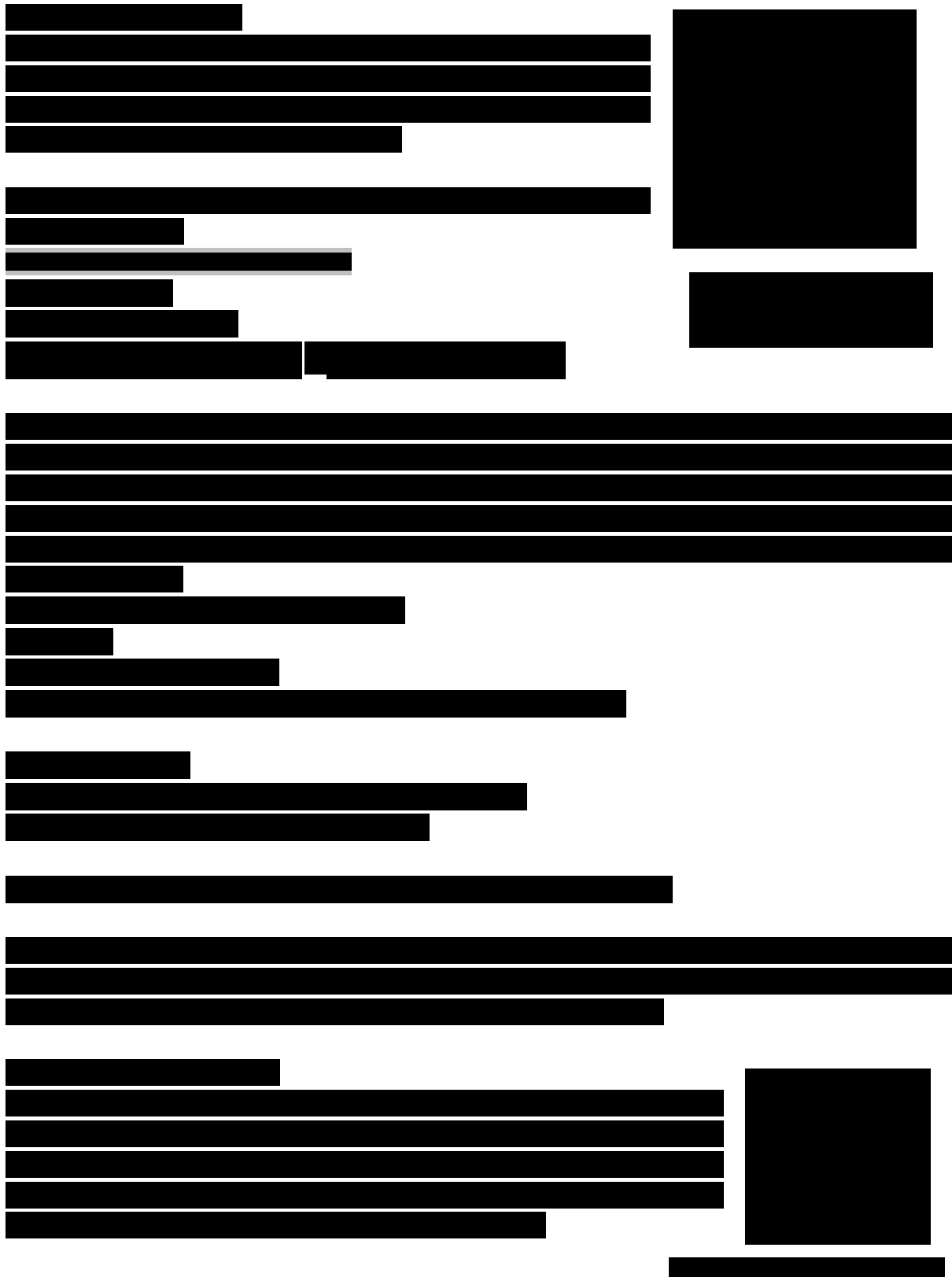
Test 2: Steam from Lavazza Amodo Mio was led into the milk at the bottom of the jug, at the same time the milk was pumped from the jug through the pump and back into the milk passing through a narrow nozzle. The same result as in test 1 was obtained.

Test 3: Not enough milk is sprayed into the milk when adding steam before the pump and foam is not created in a satisfying amount. If the steam pressure is bigger than the pressure created by the pump, the steam will take the way through the pipe that is intended to suck milk.

Test 4: Adding steam after the pump results in nice foam but there is no big difference between test 1 and 4. If the steam pressure is higher than the pressure created by the pump, the pump-motor will stop, hence the narrow nozzle.

Test 5: Same test as test 1 was executed but this time the Nespresso Aeroccino foamer was used as jug and the heat function was used. Different nozzles and different places to put the nozzles were tested. The same foam quality as in test 1 was obtained.

Test 6: Same as test 5 but the pipe connected to the pump input was perforated. This resulted in small bubbles in the milk going into the milk, unfortunately not enough foam was formed.



21. Whisk with heat

An ordinary milk whisk modified to also be able to heat the milk would be handy. If the whisk head could be heated the milk would be heated and foamed at the same time. To heat 2dl milk in 1 minute the power has to be 600W, therefore wall socket is needed. Then it loses some of its portability. It is also difficult to lead that kind of heat without heating other components and it is to small area to transfer heat to the milk in a desirable amount of time. This could be solved using flanges but the whisk would however not be safe to use.

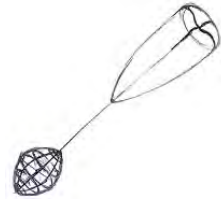
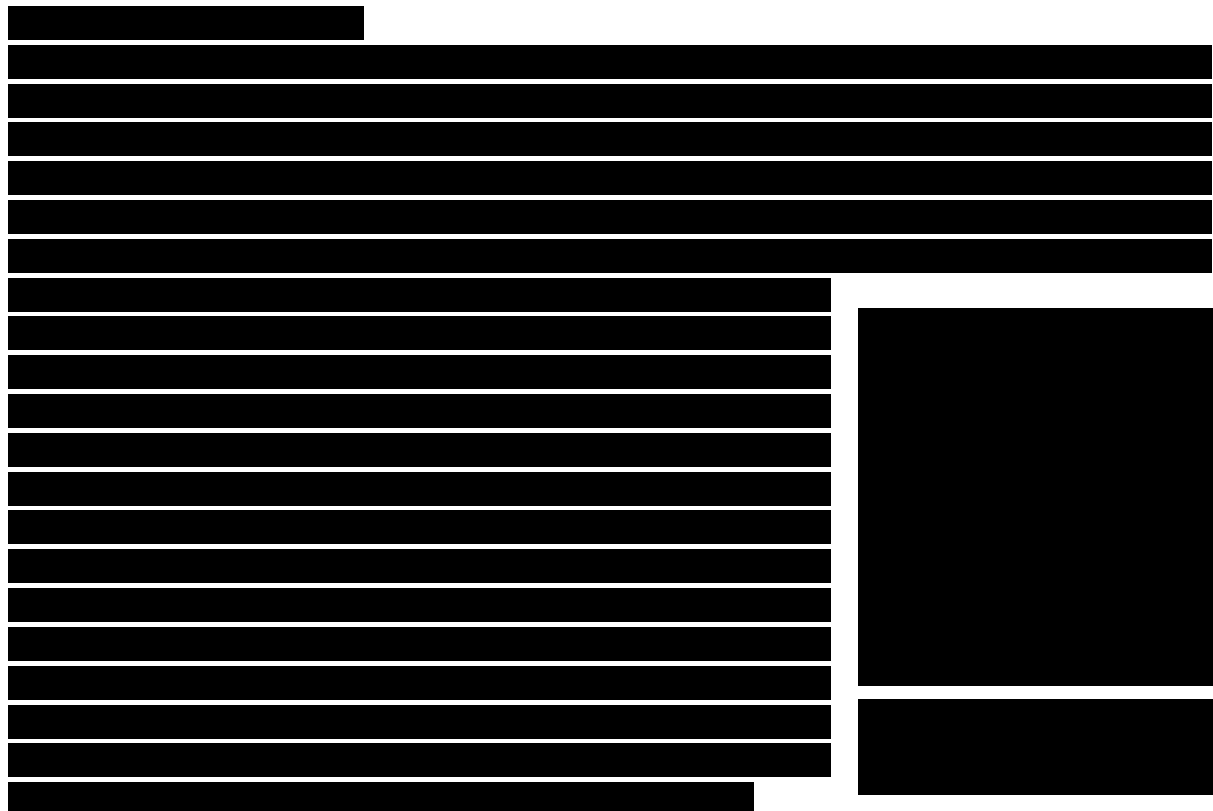


Figure 19: Whisk with heat

22. Nitrous oxide run foamer

Small containers with nitrous oxide have a pressure of 9bar and could be used as a booster to steamers. Professional barista steamers have a pressure of 9bar and they create microfoam. Unfortunately nitrous oxide is not environmental friendly and therefore it is not a good idea to use nitrous oxide as a booster.



24. Construction that drags down foam

Every technique investigated so far creates makrofoam. The concentration so far has been to come up with a technique that forms microfoam at once. When developing this concept the aim was to find a technique to easily collapse big bubbles. When swirls are formed using a whisk the foam at the surface usually stays there, the milk simply just centrifuges towards the jug wall. Spirals can be placed on the jug wall or the whisk can consist of a whisk and a spiral to get the top layer of the foam and big bubbles to be dragged down into the foam and collapse. This solution works but the difference in foam quality is not that big.



Figure 20: Construction that drags down foam

25. Froth the milk by squeezing the milk through a net

Tests showed that if the milk passes through only one net, no froth will be formed. If milk passes through 5 nets with a mesh (0.3mm opening diameter, 30% open area) foam will be formed. To form foam air have to be introduced in to the system, if pressing milk and air trough the net at the same time foam will be formed effectively. Unfortunately all tests with different meshes and mesh size have not resulted in microfoam. This product would be difficult to keep clean.

26. Improved squeeze cup

As some of the heat resistant squeeze cups (se chapter 3.6) gives a satisfying result this method was investigated further. The idea was to investigate if the technique creates better foam if only using one of the motions, squeeze or drag. If that is the case one of the motions could be removed by using valves allowing only one motion to effect the milk. Test was made to see if the foam mainly is produced when the milk is squeezed through the net with a high pressure in the milk or when the movement is creating a low pressure in the milk. This was done using a bladder run by a motor. With a non-return valve connected to an opening in the net it is possible to choose if the milk will only be squeezed through the net by over pressure or dragged through the net by low pressure. This test showed that foam is mostly produced by over pressure, but this motion does not create high quality foam. To pump the milk trough a net will almost give the same result. A squeeze cup creates high quality foam and it is suggested that in practise the two motions collaborates and helps getting almost microfoam. Also the force created by hand is quite big and great turbulence is created, which collapse big bubbles. As mentioned the low pressure motion do not create as much foam as overpressure but it may help collapse or reduce the size of the bigger bubbles.



Figure 21: Prototype to verify what different influences drag and press has on the creation of foam when using a squeeze cup

4.3 Elimination process

This section shows an overview of the different concepts. Concepts that are not feasible are marked with red, yellow if the concept is rejected for some other reason and green if the concept will be taken to the decision matrix.

4.3.1 Integrated concepts

Table 2: Elimination process regarding integrated concepts

	Solution	Not feasible/Rejected/Take to decision matrix
1	Fine air nozzle which creates bubbles	✗ Created bubbles are not small enough
2	Nozzle that makes the milk rotate	✗ Just point the nozzle instead, better instructions
3	Whisk run by the steam / Nozzle that rotates	✗ The result does not make up for the complexity
4	Friction foamer	✗ Do not create as much foam or heat as desirable
5	Use ultrasound to rupture the biggest bubbles	✗ Ultrasound does not create foam or break big bubbles
6	Carbonic acid milk frother	✗ Not tasty foam
7	Higher pressure and bigger tank	✗ Makes it possible to create microfoam

4.3.2 Cooperating concepts

Table 3: Elimination process regarding cooperating concepts

	Solution	Not feasible/Rejected/Take to decision matrix
8	Whisky glass bottom milk jug	✗ Not effective enough/Easy to do by hand
9	Something that knock the milk jug	✗ Not effective enough/Easy to do by hand
10	Steamer application	✗ Not standard nozzles / Gets too close to the table

4.3.3 Standalone concepts

Table 4: Elimination process regarding standalone concepts[illegible]

4.4 Decision matrix

All the concepts that are marked with green in the above section have been taken further to this stage. To see which of these ideas that best responds to customer requirements a decision matrix is used. The decision matrix was only done for standalone solutions, hence this is the only category including solutions that is feasible or has not already been rejected. The weight has been taken directly from the general survey (see Diagram 4: Customer requirements).

Table 5: Decision matrix





4.5 Ideas to bring to the next phase

4.5.1 Integrated solutions

A new kind of technical solution that is better than the steam foamer in terms of customer requirements (see 3.8 Customer research) have not been found regarding milk foamers that are integrated in espresso machines. Steam work both as a heating and frothing function, this result in solely a nozzle to clean. Steam is so far the best solution. Using other solutions to froth the milk requires another heating function. Another heating function often involves the milk being in contact with a hot surface and result in one more parts to clean hence the milk has a tendency of stick to the hot surface. This problem could be solved using microwaves to heat the milk but still no easy way to foam the milk without having a lot of parts to be clean have been found.

Things to be improved could be to get a higher pressure and more even and longer lasting steam flow from the nozzle using a bigger tank. With a higher pressure and bigger tank the steam nozzles also could be redesigned, with for example more holes. With higher pressure the foam result would most certainly get closer to the microfoam that is obtained with a steamer on a professional espresso machine. As mentioned professional espresso machines have a higher pressure (9bar compared to

2bar in smaller espresso machines) and a much bigger tank, this results in a more even and higher steam flow. Therefore constructing the pressure tank to be bigger and able to withstand a higher pressure would be interesting. This could easily be done but is also a question of size of the machine and also the cost, hence some parts have to be up scaled. A good instruction is also needed hence many customers do not know how to use a steam pipe in order to create microfoam. No concepts on integrated solutions are taken to the next phase in the development process.

4.5.2 Cooperating solutions

The tested cooperating product Lavazza Mio Amado Cappuccinatore (tested in chapter 3.6) prove that this solution is neither easy to use, easy to clean or makes tasty foam. Only one cooperating milk foamer that is easy to use and clean has been found. It consists of the same solution as in AEG Crema Classica. The tip of the construction can be placed at the steam nozzle on any espresso machine and create the same froth as AEG Crema Classica. This can be handy when foaming bigger volumes (more than one cafe latte) and little cleaning is required. This solution can be less convenient to use if the steam nozzle on the espresso machine is close to the bottom of the machine (the table). This will result in the extra nozzle getting too close to the table and no cup will fit under the nozzle. Also the milk can have trouble travel to the nozzle, hence long tube. No concepts on cooperating solutions are taken to the next phase in the development process.

4.5.3 Standalone solutions

Several ideas have been rejected because they are difficult to realize, for example idea number 11. Induction heated whisk. No solution so far makes microfoam, therefore it could be a good idea to concentrate on an idea that is easy to clean and that have a high freedom of design. Ordinary whisks all look the same and gives a fragile feeling. A more robust product that is as easy to use and clean as a whisk but at the same time, in an easy way heats the milk is desirable.

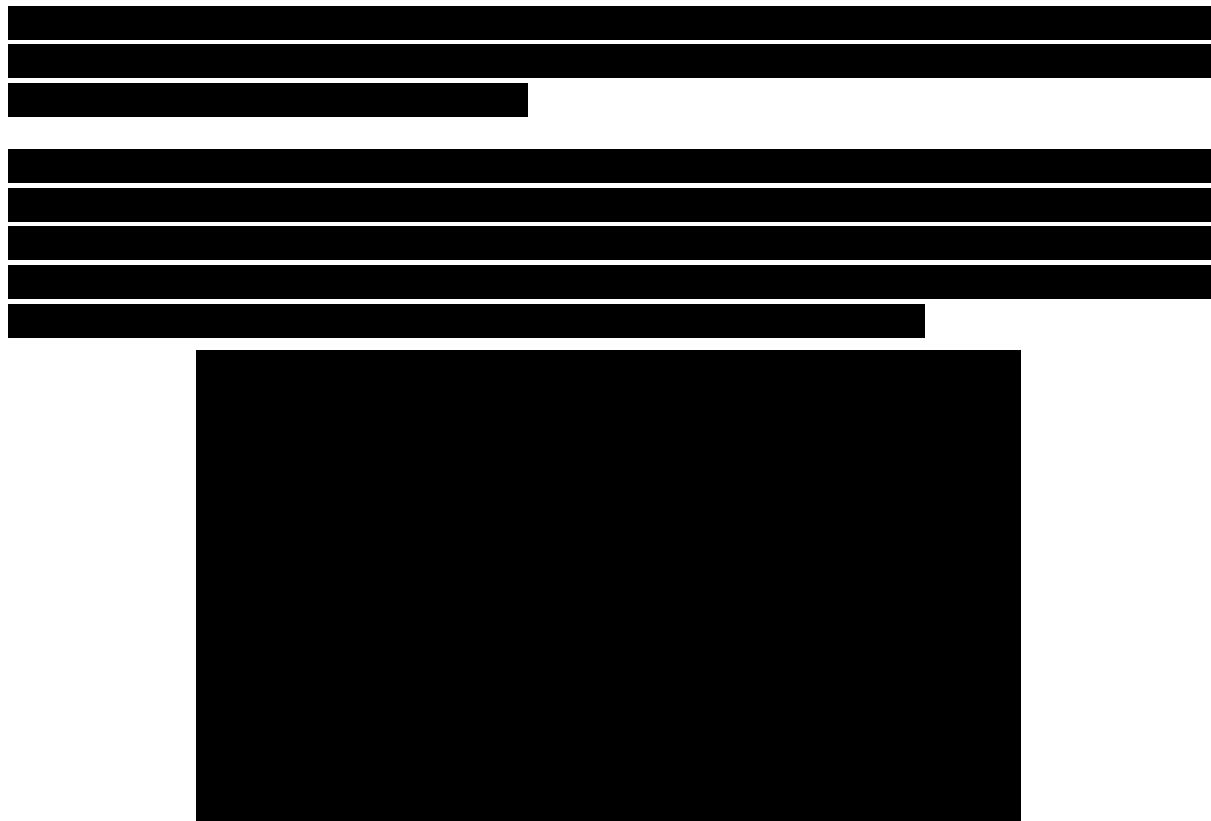


Figure 22: Composition of the concepts that will be investigated further

5 Solution and verification

To verify concepts and solutions that had made it to this phase rough prototypes had to be constructed and built. Even if prototypes involving high pressure are tested with precaution, safety and strength calculations had to be made. Also one totally new concept has been developed in this phase, see

████████████████████

11

██████████

1. *Journal of Management Studies*, 1996, 33, 1, 1-14.
 2. *Journal of Management Studies*, 1996, 33, 1, 15-29.
 3. *Journal of Management Studies*, 1996, 33, 1, 31-45.
 4. *Journal of Management Studies*, 1996, 33, 1, 47-61.
 5. *Journal of Management Studies*, 1996, 33, 1, 63-77.
 6. *Journal of Management Studies*, 1996, 33, 1, 79-93.
 7. *Journal of Management Studies*, 1996, 33, 1, 95-109.
 8. *Journal of Management Studies*, 1996, 33, 1, 111-125.
 9. *Journal of Management Studies*, 1996, 33, 1, 127-141.
 10. *Journal of Management Studies*, 1996, 33, 1, 143-157.
 11. *Journal of Management Studies*, 1996, 33, 1, 159-173.
 12. *Journal of Management Studies*, 1996, 33, 1, 175-189.
 13. *Journal of Management Studies*, 1996, 33, 1, 191-205.
 14. *Journal of Management Studies*, 1996, 33, 1, 207-221.
 15. *Journal of Management Studies*, 1996, 33, 1, 223-237.
 16. *Journal of Management Studies*, 1996, 33, 1, 239-253.
 17. *Journal of Management Studies*, 1996, 33, 1, 255-269.
 18. *Journal of Management Studies*, 1996, 33, 1, 271-285.
 19. *Journal of Management Studies*, 1996, 33, 1, 287-301.
 20. *Journal of Management Studies*, 1996, 33, 1, 303-317.
 21. *Journal of Management Studies*, 1996, 33, 1, 319-333.
 22. *Journal of Management Studies*, 1996, 33, 1, 335-349.
 23. *Journal of Management Studies*, 1996, 33, 1, 351-365.
 24. *Journal of Management Studies*, 1996, 33, 1, 367-381.
 25. *Journal of Management Studies*, 1996, 33, 1, 383-397.
 26. *Journal of Management Studies*, 1996, 33, 1, 399-413.
 27. *Journal of Management Studies*, 1996, 33, 1, 415-429.
 28. *Journal of Management Studies*, 1996, 33, 1, 431-445.
 29. *Journal of Management Studies*, 1996, 33, 1, 447-461.
 30. *Journal of Management Studies*, 1996, 33, 1, 463-477.
 31. *Journal of Management Studies*, 1996, 33, 1, 479-493.
 32. *Journal of Management Studies*, 1996, 33, 1, 495-509.
 33. *Journal of Management Studies*, 1996, 33, 1, 511-525.
 34. *Journal of Management Studies*, 1996, 33, 1, 527-541.
 35. *Journal of Management Studies*, 1996, 33, 1, 543-557.
 36. *Journal of Management Studies*, 1996, 33, 1, 559-573.
 37. *Journal of Management Studies*, 1996, 33, 1, 575-589.
 38. *Journal of Management Studies*, 1996, 33, 1, 591-605.
 39. *Journal of Management Studies*, 1996, 33, 1, 607-621.
 40. *Journal of Management Studies*, 1996, 33, 1, 623-637.
 41. *Journal of Management Studies*, 1996, 33, 1, 639-653.
 42. *Journal of Management Studies*, 1996, 33, 1, 655-669.
 43. *Journal of Management Studies*, 1996, 33, 1, 671-685.
 44. *Journal of Management Studies*, 1996, 33, 1, 687-701.
 45. *Journal of Management Studies*, 1996, 33, 1, 703-717.
 46. *Journal of Management Studies*, 1996, 33, 1, 719-733.
 47. *Journal of Management Studies*, 1996, 33, 1, 735-749.
 48. *Journal of Management Studies*, 1996, 33, 1, 751-765.
 49. *Journal of Management Studies*, 1996, 33, 1, 767-781.
 50. *Journal of Management Studies*, 1996, 33, 1, 783-797.
 51. *Journal of Management Studies*, 1996, 33, 1, 799-813.
 52. *Journal of Management Studies*, 1996, 33, 1, 815-829.
 53. *Journal of Management Studies*, 1996, 33, 1, 831-845.
 54. *Journal of Management Studies*, 1996, 33, 1, 847-861.
 55. *Journal of Management Studies*, 1996, 33, 1, 863-877.
 56. *Journal of Management Studies*, 1996, 33, 1, 879-893.
 57. *Journal of Management Studies*, 1996, 33, 1, 895-909.
 58. *Journal of Management Studies*, 1996, 33, 1, 911-925.
 59. *Journal of Management Studies*, 1996, 33, 1, 927-941.
 60. *Journal of Management Studies*, 1996, 33, 1, 943-957.
 61. *Journal of Management Studies*, 1996, 33, 1, 959-973.
 62. *Journal of Management Studies*, 1996, 33, 1, 975-989.
 63. *Journal of Management Studies*, 1996, 33, 1, 991-1005.
 64. *Journal of Management Studies*, 1996, 33, 1, 1007-1021.
 65. *Journal of Management Studies*, 1996, 33, 1, 1023-1037.
 66. *Journal of Management Studies*, 1996, 33, 1, 1039-1053.
 67. *Journal of Management Studies*, 1996, 33, 1, 1055-1069.
 68. *Journal of Management Studies*, 1996, 33, 1, 1071-1085.
 69. *Journal of Management Studies*, 1996, 33, 1, 1087-1101.
 70. *Journal of Management Studies*, 1996, 33, 1, 1103-1117.
 71. *Journal of Management Studies*, 1996, 33, 1, 1119-1133.
 72. *Journal of Management Studies*, 1996, 33, 1, 1135-1149.
 73. *Journal of Management Studies*, 1996, 33, 1, 1151-1165.
 74. *Journal of Management Studies*, 1996, 33, 1, 1167-1181.
 75. *Journal of Management Studies*, 1996, 33, 1, 1183-1197.
 76. *Journal of Management Studies*, 1996, 33, 1, 1199-1213.
 77. *Journal of Management Studies*, 1996, 33, 1, 1215-1229.
 78. *Journal of Management Studies*, 1996, 33, 1, 1231-1245.
 79. *Journal of Management Studies*, 1996, 33, 1, 1247-1261.
 80. *Journal of Management Studies*, 1996, 33, 1, 1263-1277.
 81. *Journal of Management Studies*, 1996, 33, 1, 1279-1293.
 82. *Journal of Management Studies*, 1996, 33, 1, 1295-1309.
 83. *Journal of Management Studies*, 1996, 33, 1, 1311-1325.
 84. *Journal of Management Studies*, 1996, 33, 1, 1327-1341.
 85. *Journal of Management Studies*, 1996, 33, 1, 1343-1357.
 86. *Journal of Management Studies*, 1996, 33, 1, 1359-1373.
 87. *Journal of Management Studies*, 1996, 33, 1, 1375-1389.
 88. *Journal of Management Studies*, 1996, 33, 1, 1391-1405.
 89. *Journal of Management Studies*, 1996, 33, 1, 1407-1421.
 90. *Journal of Management Studies*, 1996, 33, 1, 1423-1437.
 91. *Journal of Management Studies*, 1996, 33, 1, 1439-1453.
 92. *Journal of Management Studies*, 1996, 33, 1, 1455-1469.
 93. *Journal of Management Studies*, 1996, 33, 1, 1471-1485.
 94. *Journal of Management Studies*, 1996, 33, 1, 1487-1501.
 95. *Journal of Management Studies*, 1996, 33, 1, 1503-1517.
 96. *Journal of Management Studies*, 1996, 33, 1, 1519-1533.
 97. *Journal of Management Studies*, 1996, 33, 1, 1535-1549.
 98. *Journal of Management Studies*, 1996, 33, 1, 1551-1565.
 99. *Journal of Management Studies*, 1996, 33, 1, 1567-1581.
 100. *Journal of Management Studies*, 1996, 33, 1, 1583-1597.
 101. *Journal of Management Studies*, 1996, 33, 1, 1599-1613.<

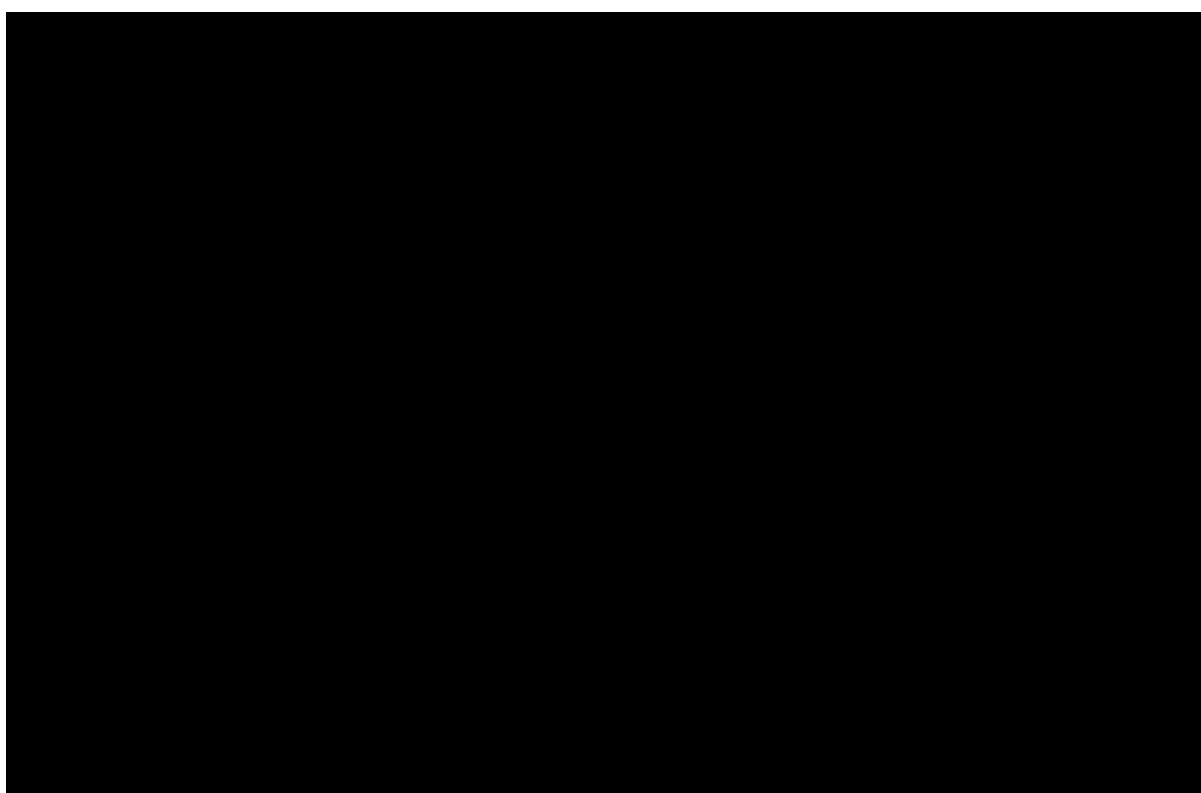
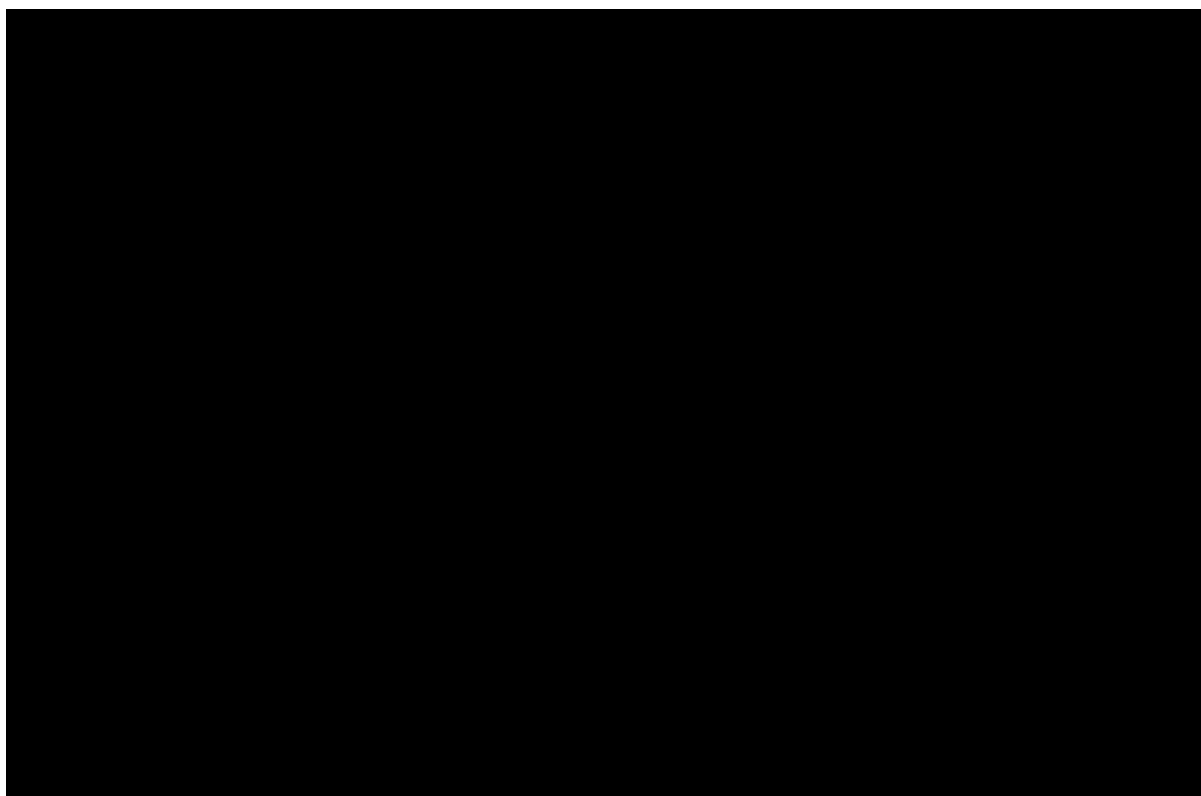
██████████

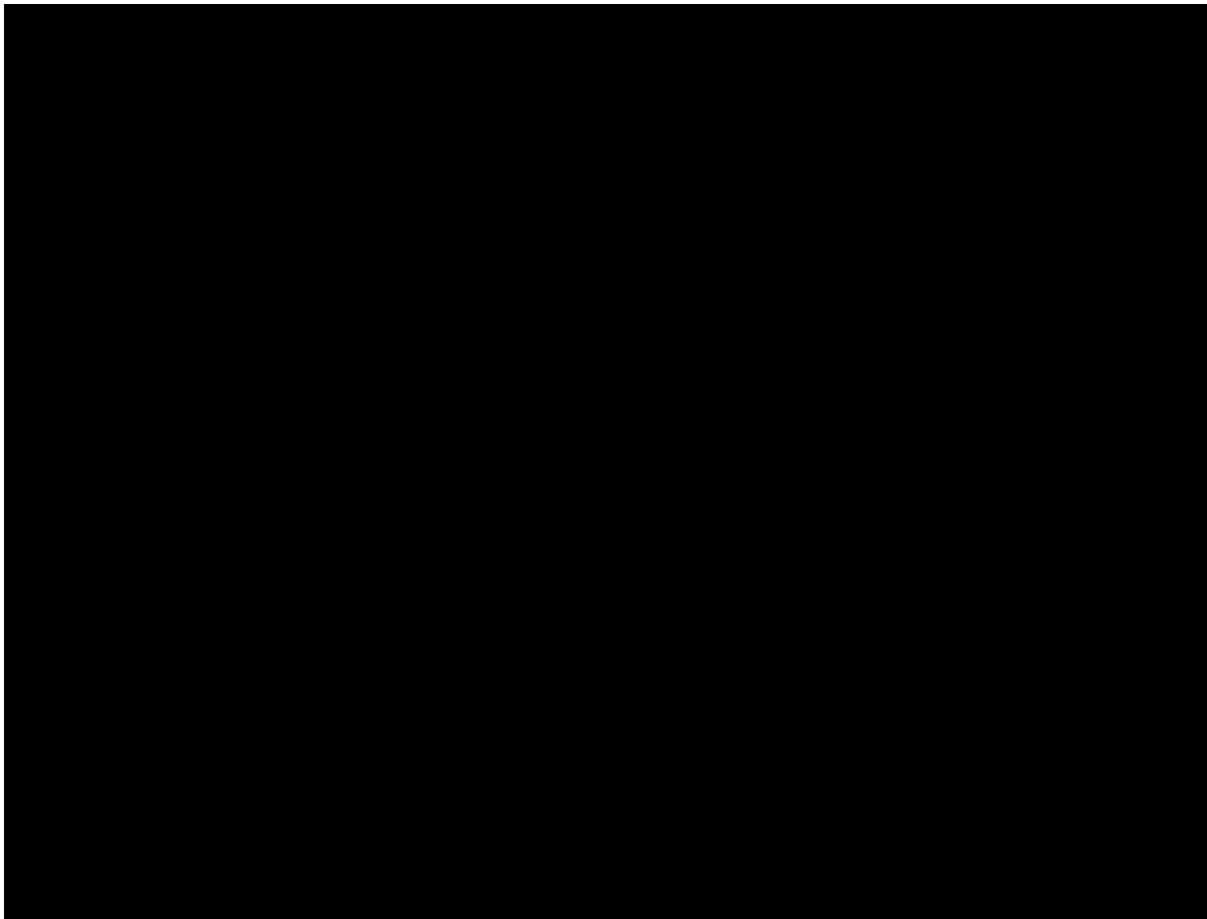
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]





[Redacted text line]

[Redacted text line]

[Redacted text block consisting of four lines]

[Redacted text block consisting of five lines]

[Redacted text line]

[Redacted text line]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[Redacted text block]

[Redacted text block]

[Redacted text block]	[Redacted text block]
-----------------------	-----------------------

[Redacted text block]

[Redacted text block]

[Redacted text block]

Table 7: [Redacted text block]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]



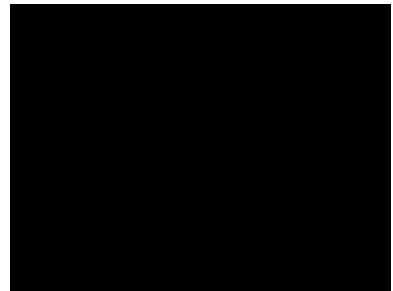
Figure 40: [REDACTED]

[REDACTED]

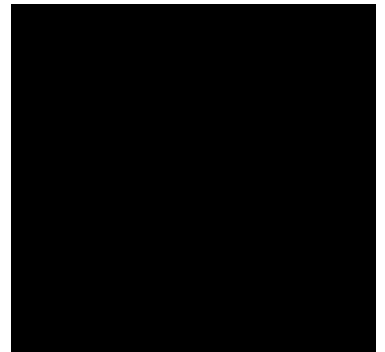
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]

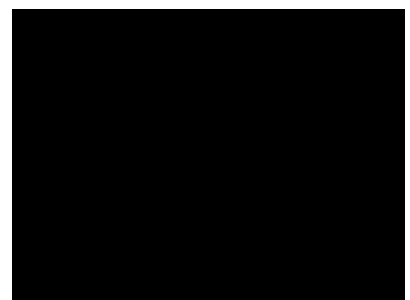
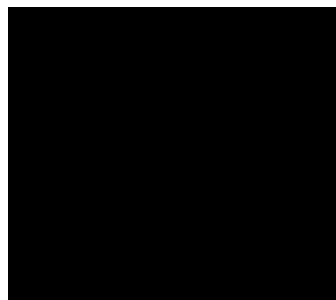
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]



████████████████████



114



[REDACTED]

[illegible]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[illegible]



[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

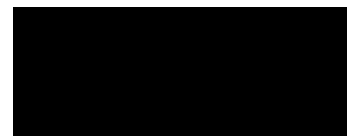
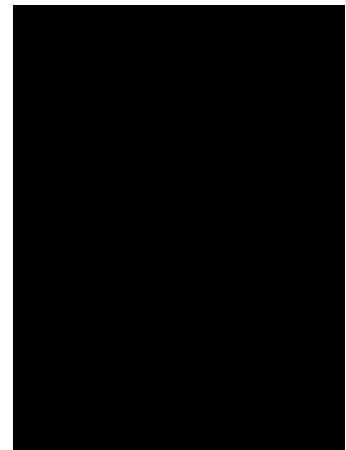
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]



[REDACTED]

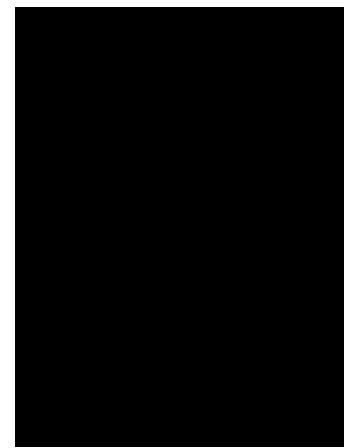
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]



[REDACTED]

[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]
[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]
[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

5.2 Ideas to bring to the next phase

[REDACTED]

Diagram 11: User friendly-Foam quality, displaying products on the market and prototypes (bold)

[REDACTED]

[REDACTED]

6 Hardware and solutions

To find what hardware to use in the final products and to build prototypes is time-consuming. Unfortunately one more iteration on the building/construction of the prototypes has to be done to get prototypes that will perform somewhat like the final products. Several tests have been performed to make sure that the concepts really are feasible. CAD models have mainly been done to illustrate what the final products can look like and to be able to order parts. As the final products most likely will be slightly different, drawings or thorough explanations of the constructions are not included in the report.

Cost to produce the product have not been investigated and is just an educated assumption from the author. Electrolux would most certainly produce the products in China and it would be time-consuming to do a research of this.

[REDACTED]

6.1.1 Construction/Material

[REDACTED]

6.1.2 Cost

[REDACTED]

6.1.3 QFD

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

6.1.4 Cost

[REDACTED]

6.1.5 QFD

[REDACTED]

7 Results

7.1 Pre-study

Nowadays microfoam is desirable to use in all coffee drinks. With the range of milk foamers existing today the only product that creates Microfoam is a professional barista steamer. The milk to use when creating microfoam is whole milk. The milk should not exceed 65°C in temperature.

Theoretically 1.7cl water in form of 100°C saturated steam is needed to heat 2dl milk from 10°C to 65°C. In practice 3.7cl water is needed.

The most important customer requirements are that the milk foamer should be easy to clean, make tasty milk foam, make natural milk foam without adding extra ingredients and that the milk foamer is easy to use.

7.2 Creation of ideas

[Redacted text block]

7.3 Solution and verification

[Redacted text block]

7.4 Hardware and solutions

These are the final prototypes

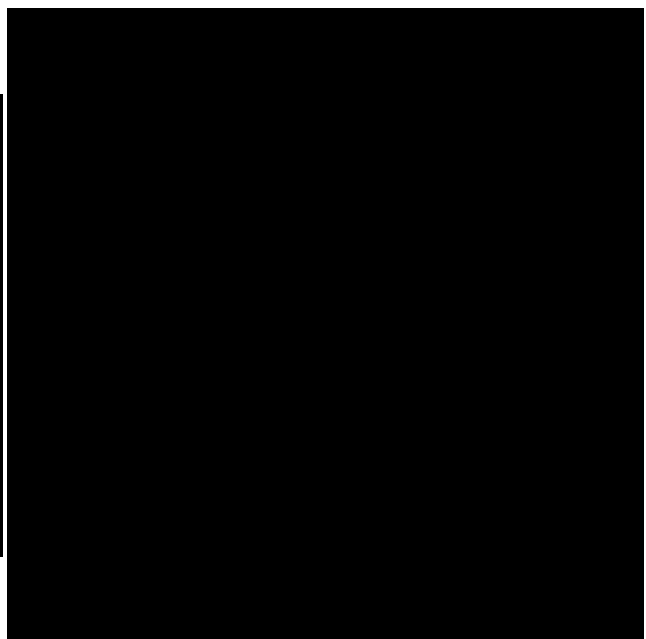
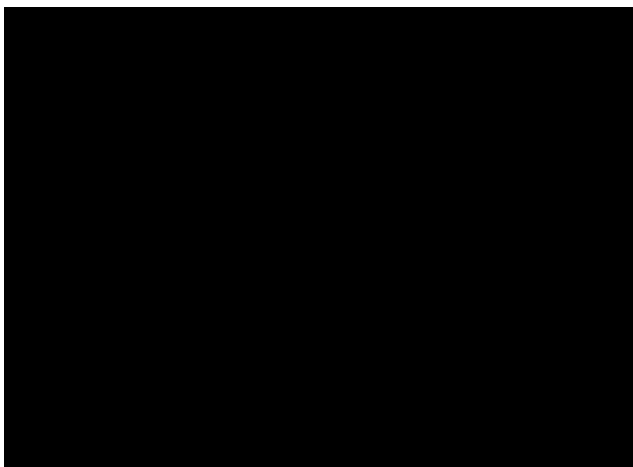
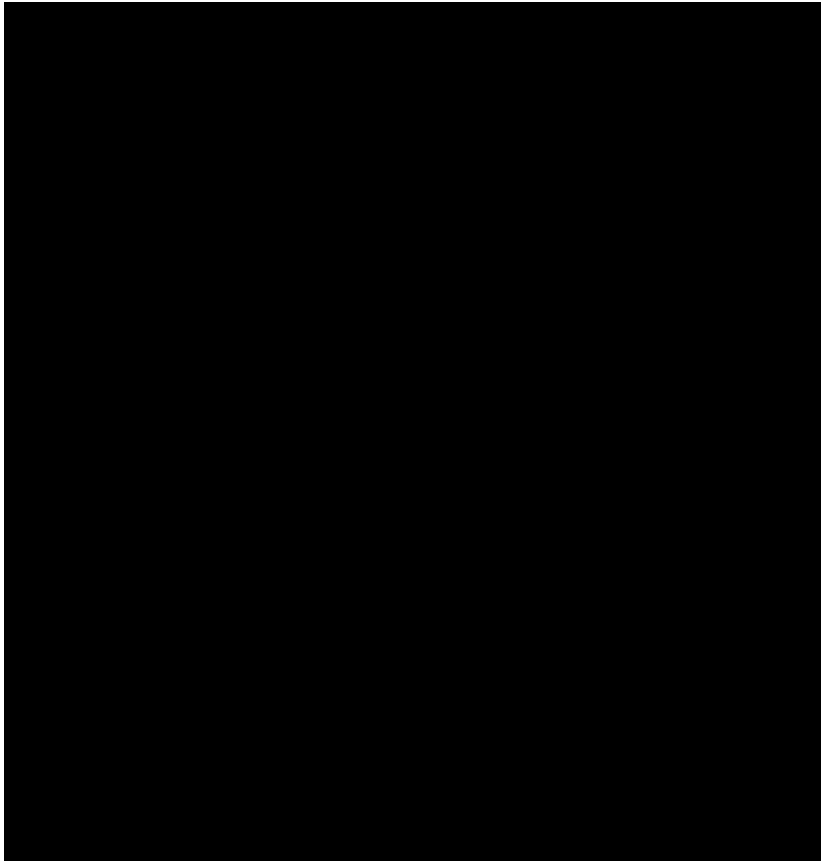


Figure 23: 

8 Discussion

8.1 Pre-study

One reason that steam from a professional barista steamer result in such nice foam is of course due to the skills the barista possess but there is most likely one theoretically reason as well. Temperature of steam increases with increasing pressure in the container. For example 2 bar over pressure (Electrolux Easypress) result in 120°C steam temperature, 9bar (professional steamer) result in 175°C steam temperature. The density of steam is approximately 4 times greater for 175°C steam compared to 120°C steam due to concentration of water. Water in steam condense when the steam is cooled, causing the volume to decrease. 175°C steam contains a significant higher amount of water than 120°C steam. High steam temperature in the tank will result in more volume and also mass will be released into the milk due to condensation causing volume of the steam inside bubbles to decrease. Also the part that is heated air will decrease in volume when the temperature is decreased. All this combined, if two equally in size bubbles are formed, the one created with higher tempered steam will end up being smaller in the foam. Simplified it can be described as the steam condensing and water mixes with the milk leaving only a small part of air inside the bubbles.

This is just a thesis and has not been verified. Looking at this aspect the safety release valves should not release steam at 2bar as it does for Electrolux Easypress Obviously the chamber can take 9bar hence when making coffee the pressure is that high. The greater temperature should neither be a problem. As more people would like to be able to make nice foam at home the author strongly believe that having as high steam pressure as professional steamers would be a strong selling argument. This could be an interesting thing to investigate, of course safety aspects have to be considered.

8.2 Creation of ideas

11. Induction heated whisk (see chapter 4.2.3) is an innovative solution. With some research it was unfortunately found that this concept was not feasible. However with some adjustments it would be feasible but convenient aspects would suffer. A specific jug with a thin and bigger area bottom could be used so that a bigger whisk could be used and the whisk would be heated sufficiently. It could be interesting to investigate if the induction plate could be modified so that this concept would be both feasible and convenient to use. This was not done due to lack of belief on the concept from the author and steering group. If the technique would have been feasible the produced foam would unfortunately have been approximately the same as if using a whisk and therefore not of high quality, but the product would have been extremely convenient, simple to use and to clean.

8.3 Solution and verification



8.4 Hardware and solutions

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

9 Recommendations and how to continue with the project

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

10 Conclusions

[REDACTED]

[REDACTED]

11 Vocabulary

Milk foamer: According to the author it refers to a device that is able to create microfoam.

Milk frother: According to the author it refers to a device that is able to create macrofoam but not microfoam.

Microfoam: High quality homogeneous foam with small bubbles, and low viscosity.

Macrofoam: Low quality foam non homogeneous, foam with large bubbles and high viscosity.

12 Reference List

(2010, 02 16). Retrieved 02 16, 2010, from Electrolux: <http://www.electrolux.com>

Azizian, K. (2010, February 16). Stockholm.

Barista Technique: Frothing Milk. (n.d.). Retrieved February 5, 2010, from Home-barista: <http://www.home-barista.com/espreso-guide-frothing-milk.html>

Bickford, J. H. (1995). *An introduction to the design and behavior of bolted joints*. New York: Marcel Dekker, Inc.

Cengel, Y. A., Turner, R. H., & Cimbala, J. M. (2008). *Fundamentals of Thermal-Fluid Sciences*. New York: McGraw Hill.

esp@cenet. (2010, 03 10). Retrieved 03 10, 2010, from Patent och registreringsverket: <http://se.espacenet.com/search97cgi/s97.cgi.exe?Action=FormGen&Template=se/en/home.htm>

Hiemenz, P. C., & Rajagopalan, R. (1997). *Principles of colloid and surface chemistry*. New York: Marcel Dekker, inc.

Hoffmann, J. (2006, June 13). *Foams*. Retrieved February 10, 2010, from Jimseven: <http://www.jimseven.com/2006/06/13/foams/>

Ingelsta, E., Rönngren, R., & Sjöberg, S. (2004). *Tefyma*. Lund: KFS Lund AD.

International standard. (2006). Geneva: International Electrotechnical Commission.

Johannesson, H., Persson, J.-G., & Pettersson, D. (2004). *Produkt utveckling*. Stockholm: Liber AB.

Kamath, S., Huppertz, T., Houlihan, A. V., & Deeth, H. C. (2008). The influence of temperature on the foaming of milk. *International Dairy Journal*, 994-1002.

Kano, N., & Nobuhiku Seraku, F. T. (1984). Attractive quality and must-be quality. *Journal of the Japanese Society for Quality Control*, 9.

(2003). *Product Creation Process*. Stockholm: Electrolux.

Product Creation Process. (2003). Stockholm: Electrolux.

Protein Denaturation. (n.d.). Retrieved February 14, 2010, from Bioinformatics: http://www.imb-jena.de/~rake/Bioinformatics_WEB/proteins_denaturation.html

Råvarorna: mjölken och kaffet. (n.d.). Retrieved February 10, 2010, from Arla Foods AB: http://www.ungakockar.se/Sites/Storkok/Storkok_____2790.aspx

Sanmann, F. P., & Ruehe, H. A. (1929). *Some factors influencing the volume of foam on milk*. Illinois: University of Illinois.

Skumma mjölk som ett proffs. (n.d.). Retrieved February 4, 2010, from Arla Foods AB: http://www.arla.se/upload/Barista/ny_Barista_folder.pdf

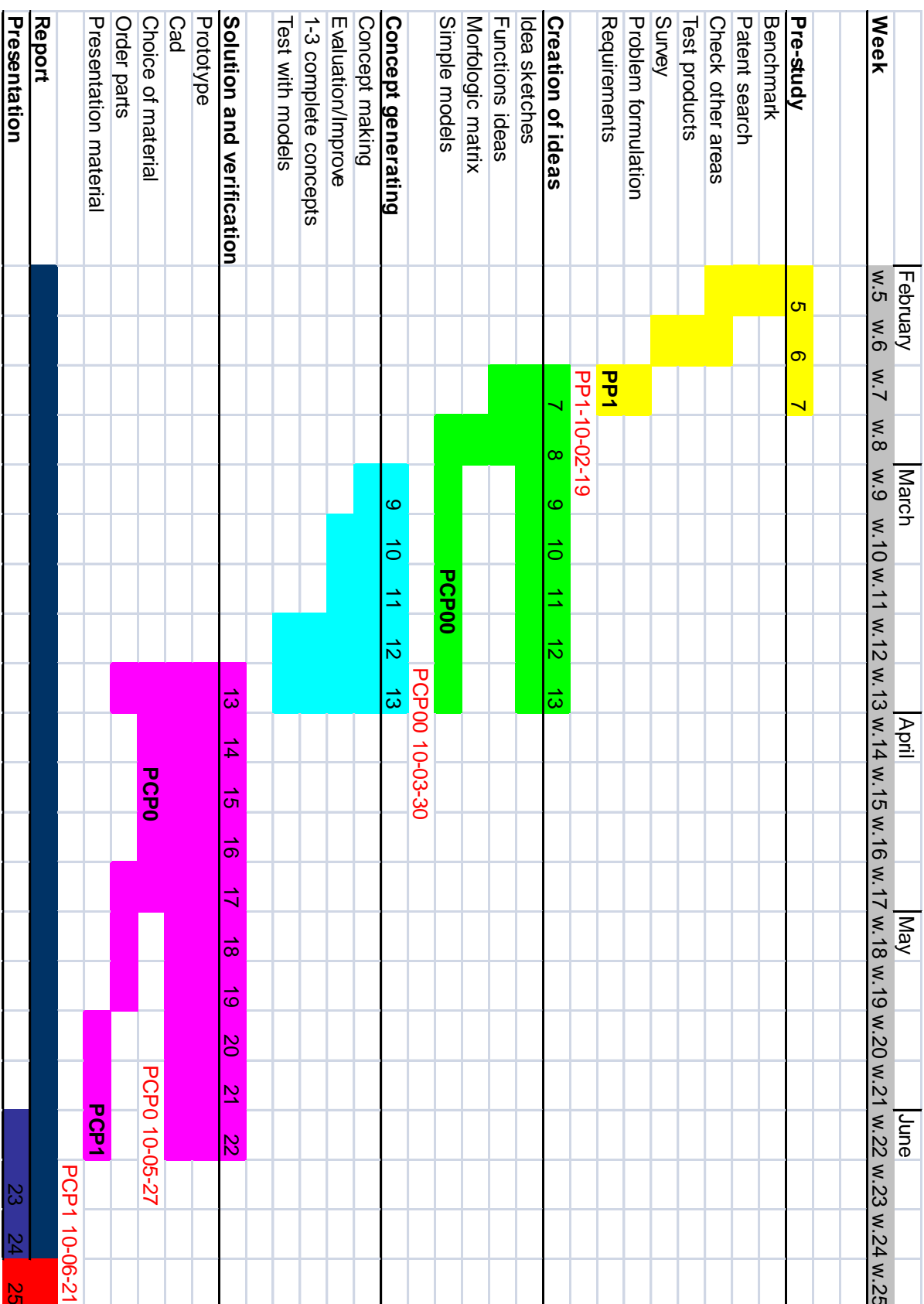
Spreer, E. (1995). *Milk and dairy product technology*. New York: Marcel Dekker, inc.

Surface Tension and Bubbles. (n.d.). Retrieved February 28, 2010, from hyperphysics: <http://hyperphysics.phy-astr.gsu.edu/Hbase/surten2.html>

The Milk Frothing Guide. (n.d.). Retrieved February 24, 2010, from coffeegeek: <http://coffeegeek.com/guides/frothingguide/milk>

Weaire, D., & Hutzler, S. (1999). *The Physics of Foams*. Oxford: Oxford University Press.

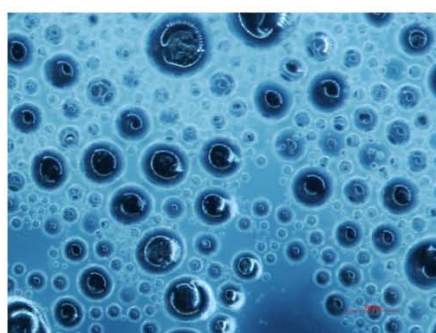
Appendix A: Gantt Timetable



Preliminary checkpoint meetings in black, checkpoint meetings in reality marked with read.

Appendix B: Photos of foam

**Electrolux
Cremapresso
steamer**



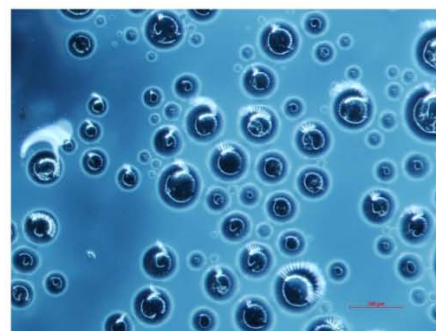
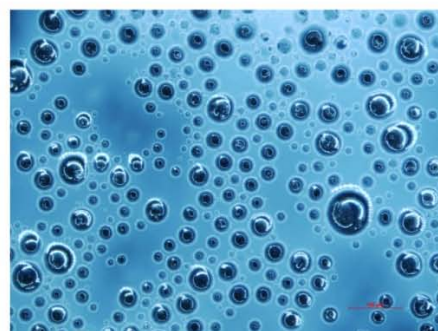
**Lavazza
Amado mio
steamer**



**Lavazza
Amado mio
steamer
and
whisk**



**OBH nordica
cafe crema
whisk**



[REDACTED]

[REDACTED]

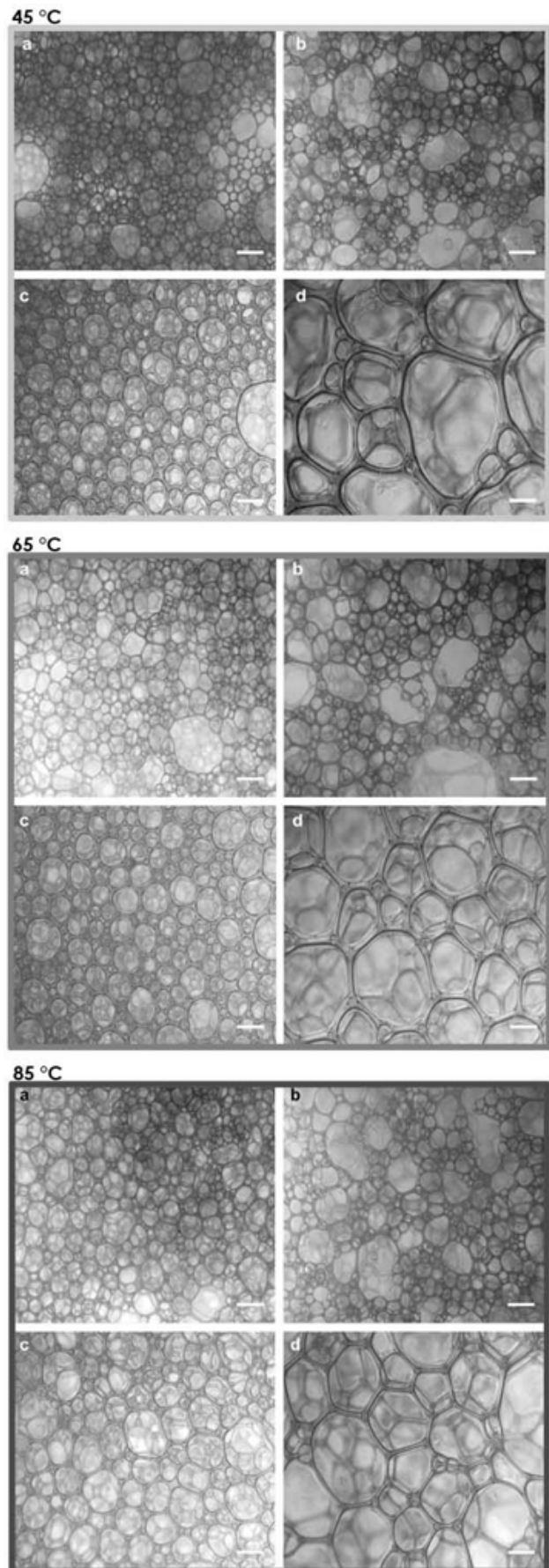
Appendix D: Images of foams

Images of foam formed at 45°C, 65°C and 85°C from:

- (a) Pasteurized homogenized whole milk immediately after foaming
 - (b) Pasteurized homogenized whole milk at half-life
 - (c) Pasteurized skim milk immediately after foaming
 - (d) Pasteurized skim milk at half-life.
- Bar=1000µm.

Half-life, is the time (in minutes) required for the foam to collapse to half its original volume.

(Kamath, Huppertz, Houlihan, & Deeth, 2008)



Appendix E: Bubble size of foams

Distributions of bubble sizes of foams formed from pasteurized homogenized whole milk and pasteurized skim milk at:

- (a) 45°C
- (b) 65°C
- (c) 85°C

Legend:

A = pasteurized homogenized whole milk, fresh foam.

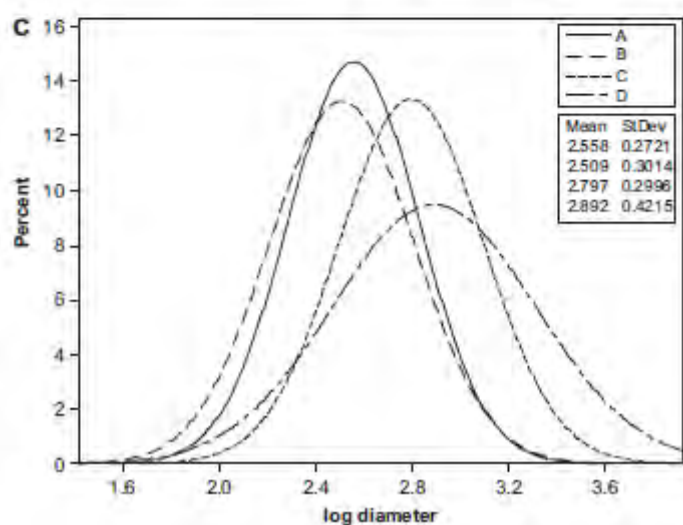
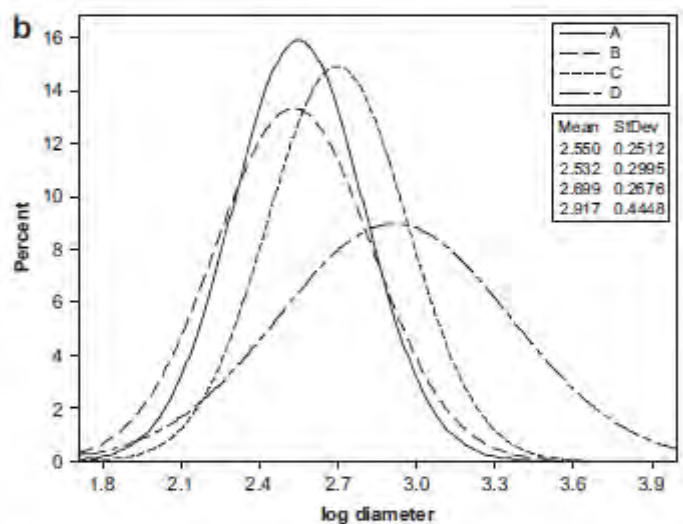
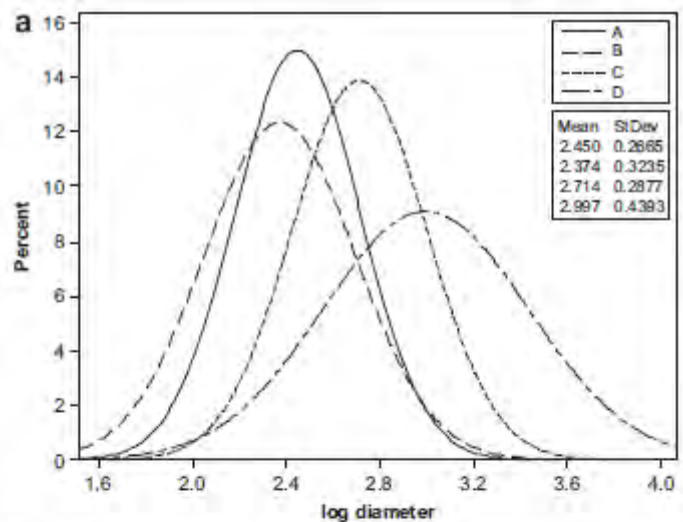
B = pasteurized homogenized whole milk foam at half-life

C = pasteurized skim milk, fresh foam.

D = pasteurized skim milk foam at half-life.

Half-life, is the time (in minutes) required for the foam to collapse to half its original volume.

(Kamath, Huppertz, Houlihan, & Deeth, 2008)



Appendix F: International standard

CEI IEC INTERNATIONAL STANDARD 60661 Edition 2.2 2006-02 Edition 2:1999

Methods for measuring the performance of electric household coffee makers

27 Steam function to froth-up milk and to heat-up water

27.1 Steam function to froth-up milk

A glass container with a thickness of about 2 mm having an inner diameter of $80 \text{ mm} \pm 2 \text{ mm}$ and a height of $75 \text{ mm} \pm 2 \text{ mm}$ is placed perpendicular and centered below the steam tube of the appliance. The distance of the outlet of the steam tube to the inner bottom of the container shall be $10 \text{ mm} \pm 1 \text{ mm}$. An amount of $0,1 \text{ l} \pm 0,001 \text{ l}$ of water is put into the glass container, and the water level is marked as level 1. An additional amount of $0,05 \text{ l} \pm 0,001 \text{ l}$ is then put into the glass container, and the water level is marked as level 2. An extra amount of $0,05 \text{ l} \pm 0,001 \text{ l}$ is added on top of level 2 and that level is marked as level 3 (for water levels, see Figure 1). A supporting surface having a thermal isolation may be used (see Figure 2). NOTE Varying steam tubes with different steam nozzles may cause differences in levels 1, 2 and 3

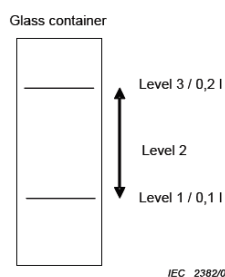


Figure 1 – Markings for levels 1, 2, 3

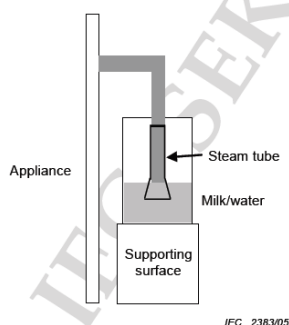


Figure 2 – Test assembly steam function

After that the glass container is emptied and dried. The water container of the appliance is then filled with the maximum quantity of cold water as assigned by markings, labels or similar instructions of the manufacturer. In case of absence of such instructions, the water container is filled with the maximum quantity of cold water. In order to avoid residual water in the steam valve, the steam function has to be operated before the test at least three times for about 5 s. The glass container is then filled with $0,1 \text{ l} \pm 0,001 \text{ l}$ of homogenized milk with a fat content of approximately 3,5 % at a temperature of $8 \text{ }^{\circ}\text{C} \pm 1 \text{ }^{\circ}\text{C}$. A watertight thermocouple of class 1 according to IEC 60584-2, accurate to $\pm 1,5 \text{ K}$ and having a nominal diameter of 0,25 mm, is placed beside the steam tube and approximately 5 mm away and 10 mm below the marking for level 2 of the glass container. The mass ML1 of the glass container including the milk shall be determined on a balance having an accuracy of at least 0,1 g and recorded. The mass ML1 is expressed in grams. After that the glass container is placed in the same way as

described for the marking procedure (see Figure 2). The appliance is operated with any controls at the positions specified by the manufacturer. In absence of such instructions, the steam function is operated at the max. setting of the steam function. The steam function of the appliance is then operated until the upper level of the frothed-up milk reaches the marked level 3. The time t_F to froth-up the milk to level 3 (double volume) shall be determined and noted. The froth-up time t_F is expressed in seconds and rounded off to the next second. The temperature T to the froth-up the milk to level 3 is measured with a temperature-recording instrument (accurate to ± 3 K) and is noted. Immediately after the frothing-up procedure the decomposition time t_{L2} of the frothed-up milk is determined and noted. t_{L2} is the time taken for the volume of frothed-up milk to reduce to level 2 by natural loss of gas (air) and returning partly into liquid state. The decomposition time t_{L2} is expressed in seconds and rounded off to the next second. The time t_{L2} is determined while retaining the glass container at the same position as used for the frothing-up procedure. NOTE This test is carried out to assess the quality of the frothing-up process and the stability of the frothed-up milk relating to bubble size and stability time. The mass $ML3$ of the glass container with the frothed-up milk shall be determined on a balance having an accuracy of at least 0.1g and noted. The mass $ML3$ is expressed in grams. NOTE Special care has to be taken collect any dripping milk after the test. The measurement of the mass of the milk, including water from the steam function, has to be made after the dripping from the steam tube has finished. The water absorption MW of the frothed-up milk shall be determined and noted. The water absorption MW of the frothed-up milk is calculated as follows: $MW = ML3 - ML1$ The result of the test is the water absorption MW of the frothed-up milk and is expressed in grams per 0,1 l of milk and rounded off to 0,1 gram.

27.2 Steam function to heat-up water

A glass container as described in 27.1 is filled with $0,2\text{ l} \pm 0,001\text{ l}$ of water at a temperature TW of $15^\circ\text{C} \pm 1^\circ\text{C}$. The mass $ML4$ of the glass container including the cold water shall be determined on a balance having an accuracy of at least 0,1 g and recorded. The mass $ML4$ is expressed in grams. After that the glass container is placed in the same way as described for the marking procedure. In order to avoid residual water in the steam valve the steam function has to be operated before the test at least three times for about 5 s, before the glass container is placed in position. A watertight thermocouple of class 1 according to IEC 60584-2, accurate to $\pm 1,5$ K and having a nominal diameter of 0,25 mm is placed beside the steam tube and approximately 5 mm away and 20 mm below the marking for level 2 of the glass container. The steam function of the appliance is then operated under the same conditions described in 27.1 for 120 s. The temperature T_{120} of the heated-up water shall be measured with a temperature-recording instrument. The measurement shall be accurate to ± 3 K. The rise in temperature ΔT shall be determined and noted. The rise in temperature ΔT is calculated as follows: $\Delta T = T_{120} - TW$ The result of the test is the rise in temperature ΔT for the heated-up water expressed in K rounded off to 1 K. The mass $ML5$ of the glass container with the heated-up water including absorbed water from the steam function shall be determined on a balance having an accuracy of at least 0,1g and noted. The mass $ML5$ is expressed in grams. NOTE Special care has to be taken to collect any dripping water after the test. The measurement of the mass of the water, including water from the steam function, has to be made after the dripping from the steam tube has finished. The steam (water) absorption MST of the heated-up water shall be determined and noted. The steam (water) absorption MST of the heated-up water is calculated as follows: $MST = ML5 - ML4$ The result of the test is the steam (water) absorption MST of the heated-up water and is expressed in grams per 0,2 l of water and rounded off to 0,1 gram. NOTE If the manufacturer does not describe the steam function to heat-up water this test is not carried out.

Appendix G: Lab standard

5.1 | Heat up time to steam | Time from when the steam function is activated until the ready indication is given. Start from “ready for coffee” mode.

5.2 | Water amount before | The water amount coming out in a cup before a steam comes, steady steam flow comes.

5.3 | Time to reach 50 K by | Time to reach 50 K temp increase in 100 ml water steam function of 15 deg. Use a paper or plastic cup with thin walls.

5.4 | Energy to reach 50 K by | Energy to reach 50 K temp increase in 100 ml steam function | water of 15 deg. Measured from start to 1 min after 50 K is reached.

5.5 | Steam flow (g/s) | Measure how much steam that is captured in a cup with 100 ml cold water in 30 sec. Let out the first water from the steam nozzle. The measurement shall be done just after the ready to steam indication. Recalculate to g/s.

5.6 | Frothing result (score 1-3) |

3=good

2=acceptable

1=bad

Grade 3

The volume shall increase at least 75 %, in max 30 sec. Measure the temperature in the milk at the same time. The frothing must be interrupted if the temperature reaches 65 deg, otherwise the milk will be degraded and starts to be burned. The foam shall consist of small bubbles which are stable. Not large bubbles which will collapse fast.

Grade 2

The bubbles/foam are still ok, but the volume is not doubled but shall be increased with about 50 % in any case.

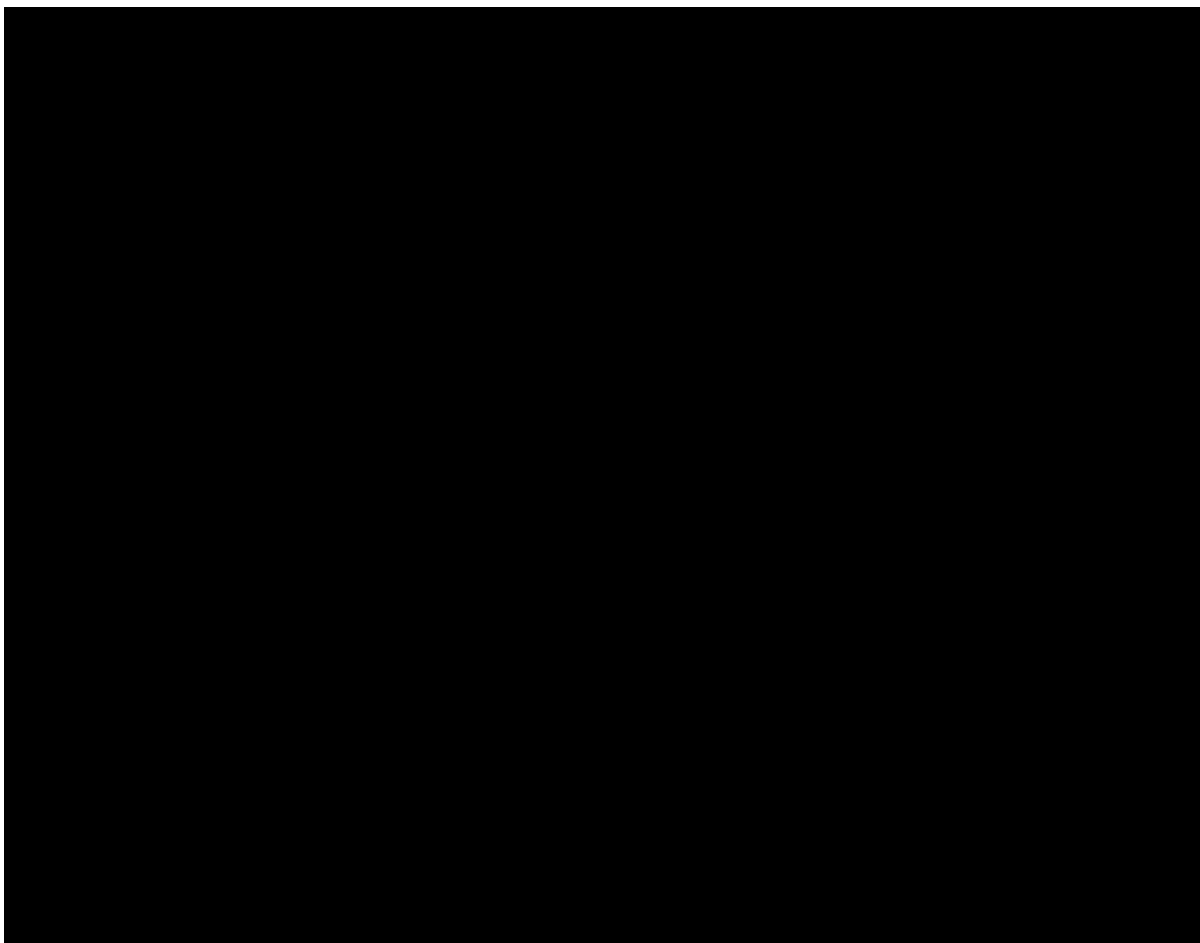
Grade 1

The volume increase is small, less than 50 %. Also if the increase is large, but the bubbles are unstable so the foam will decrease fast.

100 ml fresh milk shall be used. The temperature shall be 8 ± 1 °C. Use a milk with fat content of 1.5-3.5 %. You can use a transparent glass and take a photo on it.

5.7 | Time to double the | Take time from start until the volume is doubled
| volume | or 65 °C is reached.

Appendix H: Main tests



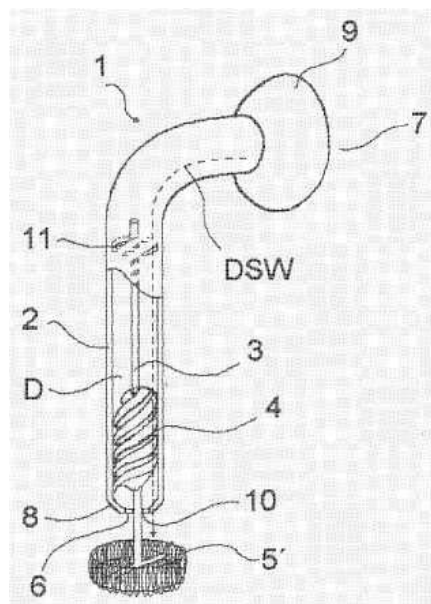
Appendix I: Patent scan

Patent number: WO 2006072484 (A1)

Application number: WO2005EP55601 20051027

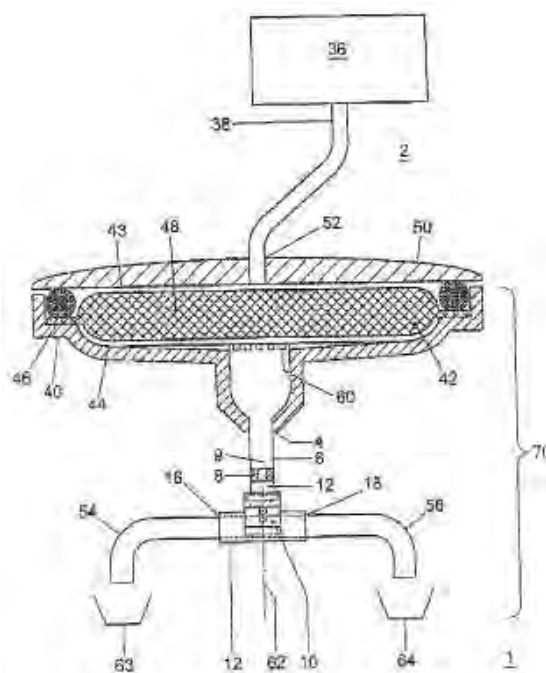
Applicant: BSH BOSCH SIEMENS HAUSGERAETE [DE]; KRAMER SIEGMUND [DE]; MEYER BRIGITTE [DE] +

The invention relates to a **milk froth** (1) producing device comprising a steam pipe (2) whose first end (7) is connected to a steam producing source for supplying steam to said pipe (2). The steam (D) runs along a steam flow path (DSW) in the steam pipe (2) to a steam flow opening (6) which is placed at the steam pipe (2) second end (8) and exits therefrom through said a steam flow opening (6). A rotatably mounted **froth** member (5) which is driven by the steam (D) running through the steam pipe (2) is arranged the outside thereof in the steam flow opening (6) area. The inventive device (1) is characterised in that the steam (2) is closed on all sides along the steam flow path (DSW).



US 2005139082 (A1)

An apparatus for preparing a beverage fit for consumption with a fine-bubble **froth** layer, such as coffee or **milk** with a fine-bubble **froth** layer, provided with a beverage unit for dispensing low pressure a beverage to be processed, at least one nozzle, which is in fluid communication with the beverage unit for feeding the beverage to the nozzle to generate a jet of the beverage by means of the nozzle, and a collecting unit, into which the jet squirts to obtain the beverage with the fine-bubble **froth** layer. The collecting unit is then provided with a tubular chamber with at least one open end for dispensing the beverage with the fine-bubble **froth** layer, the nozzle and the collecting unit being in fluid communication with each other such that the jet squirts against an inner wall of the tubular chamber for beating, in the tubular chamber, air into the beverage to obtain the beverage with the fine-bubble **froth** layer, which, in use, leaves the tubular chamber via the at least one open end.

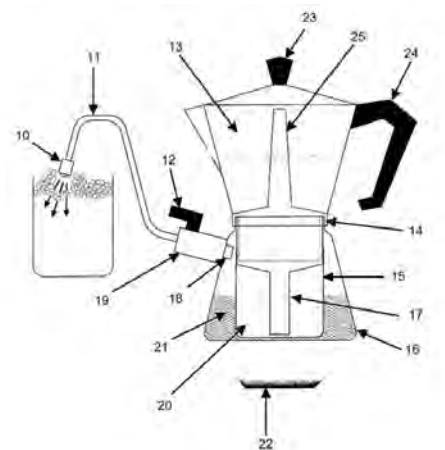


DE20318806 (U1)

DE20032018806U 20031127

OSKO BLASIUS [DE] +

The espresso maker is assembled of an upper part (13) with lid, spout and handle (24) and a lower part (16) for the accommodation of a funnel-shaped insert (17) containing the coffee powder and a cylindrical container (15) positioned around the funnel for the water required for making the espresso. When the water, present in a second container (21) accommodating the arrangement of funnel (17) and cylinder (15), starts boiling, The steam is guided through a tap (12, 19) at the outer surface of the lower part (16) and a tube (11) into a **milk** container, creating a **froth** to be used for preparing a cappuccino.

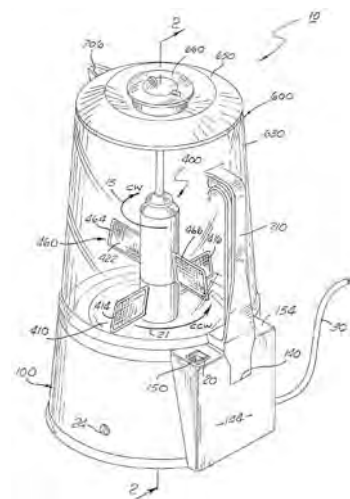


US2001002891 (A1)

US19990352377 19990713

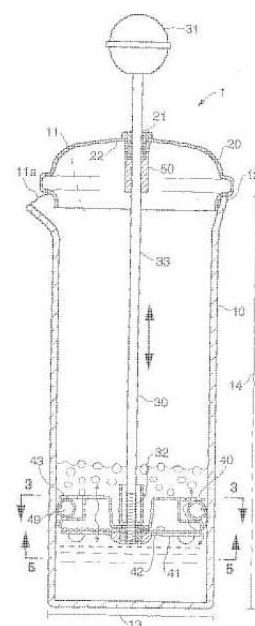
STEPHEN W FRANKEL [US] +

The invention relates to an automatic beverage **milk foamer**. The beverage **milk foamer** includes a lower housing assembly having a motor coupled to a gear train. The gear train may be removeably coupled to an upper paddle group and a lower paddle group disposed within a container. Each paddle group rotates about the longitudinal axis of the container in opposite directions. Within each paddle group is at least one paddle where each paddle is formed of a frame having mesh disposed within the frame. Other embodiments are disclosed.



US5939122 (A)

A method which permits the **frothing** of a liquid, such as **milk**, without the need for the traditional steam and/or electricity. In one embodiment of the invention, the apparatus has a container for holding the liquid, a cylindrical element, such as a rod, which extends vertically through the container's lid for the length of the container and terminating in a plunger device which is used to rapidly pump and agitate the liquid in the container to accomplish the **frothing** of the liquid. The preferred embodiment of the plunger has at least three main parts which includes a top plate and a base plate which are connected with a screen between them for permitting the flow through of the liquid. Also, between the top and bottom plates of the plunger is a spring which is positioned about the outer edges of the screen to bias the screen in close contact with the inner wall of the container, such that the plunger will move slidably along the inner wall of the container when the plunger is moving rapidly through the container of liquid to **froth** the liquid. The plunger and its components (except for the screen) have a diameter which is slightly less than the inside diameter of the container such that the plunger can slidably move along, and in contact with, the inner wall of the container when the plunger is in motion.

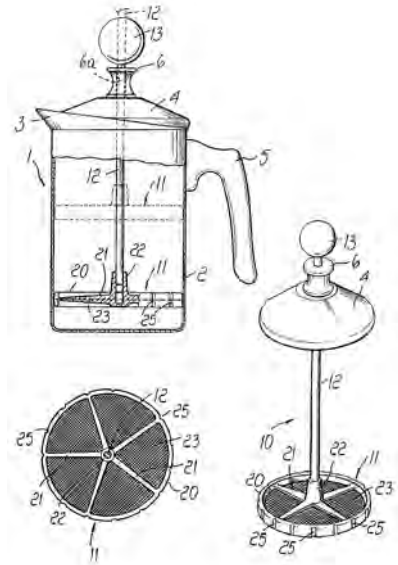


USRE37137 (E1)

US19970921204 19970827

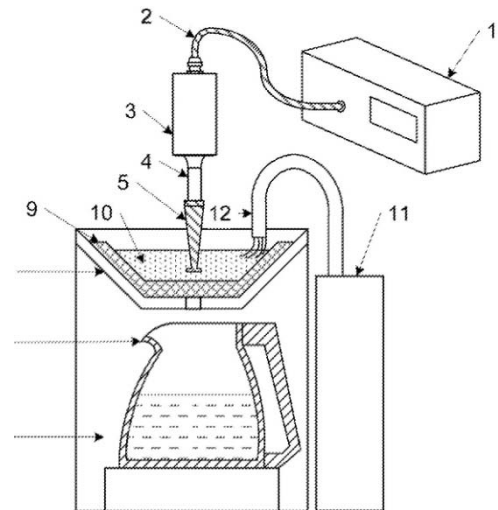
FRABOSK CASALINGHI SPA [US] +

A **milk** jug with **froth**-forming device for making cappuccino and the like, including a container body that can be closed with a lid that supports and guides a **froth**-forming element, which is constituted by a plunger element associated with a rod that protrudes from the lid. The plunger element has a disk-like element formed by a circumferential rim that is connected, by spoke-like arms, to a central hub in which the rod is inserted. The spoke-like arms retain a mesh affecting the entire surface of the disk-like element, and the spoke-like arms decrease in thickness from the hub towards the outer rim to provide flexibility on the outer portion of the disk-like element so as to increase the inclusion of air particles inside the liquid upon a reciprocating motion of the plunger element.



WO2008022161 (A2)

Method and device for producing beverages from coffee beans using ultrasound energy is disclosed. Ultrasonic energy is delivered to coffee beans to produce an improved coffee beverage. The use of ultrasound energy may have multiple effects such as the extraction of flavor solutes from the coffee beans or the sanitization of the resulting beverage. Ultrasound energy may also be used to help mix **milk** with espresso in order to produce a cappuccino or a latte; the ultrasound energy may also heat the **milk** or produce a **milk froth**. The use of ultrasound energy to produce beverages from coffee beans may result in a more flavorful and safer beverage for consumption.

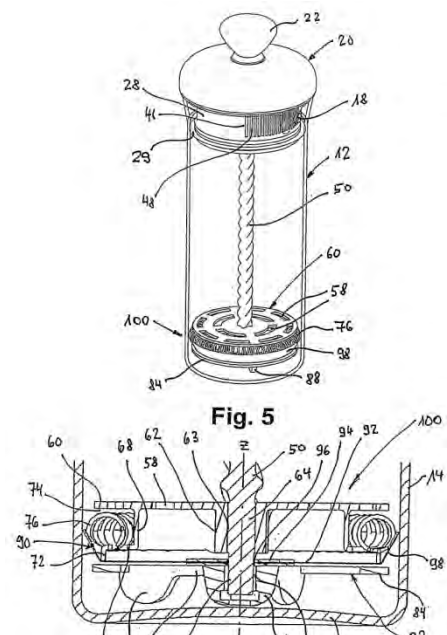


WO2008028308 (A1)

WO2007CH00428 20070829

PI DESIGN AG [CH]; BODUM JORGEN [CH] +

In a **milk frothing** device (10) having a container (12), a lid (20), an operating rod (50) which is displaceably mounted in a through-passage (38) in the lid (20) in its axial direction (z), and a piston (100) which is fixed to the free end of the operating rod (50) and has a foam-generating screen (80, 82, 84), the operating rod is a threaded spindle (50) and the through-passage (38) in the lid (20) has an internal thread (40) which corresponds to the thread of the threaded spindle (50). The combination of the movement of the piston in the axial direction together with a simultaneous rotary movement leads to rapid **froth** formation.

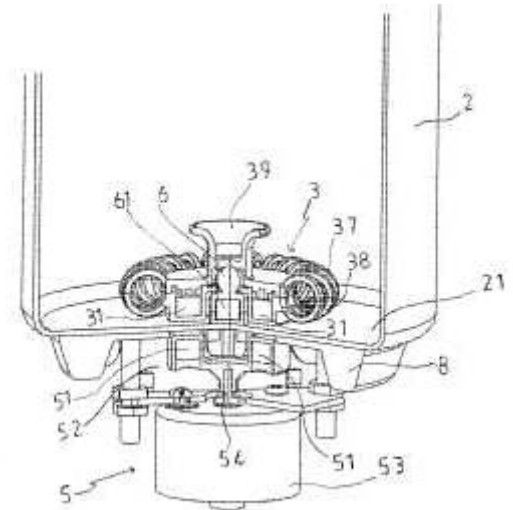


WO 2009135759 (A1)

WO2009EP54775 20090422

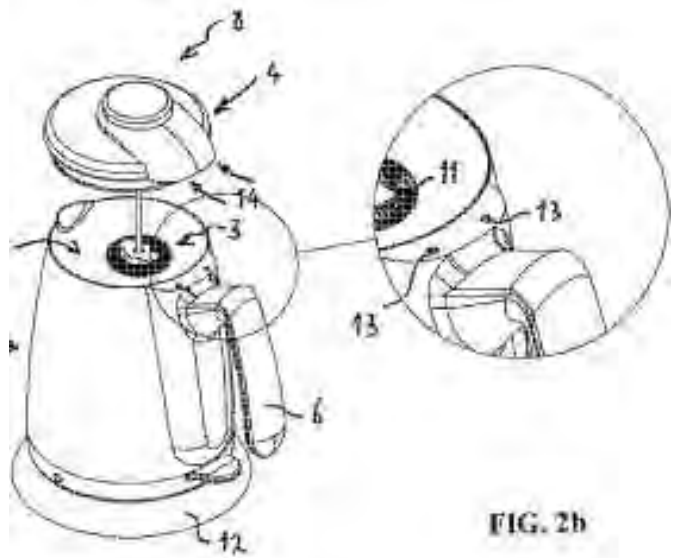
CIE MEDITERRANEENNE DES CAFES [FR]; BLANC JEAN-PIERRE [FR]; GOERING ALAIN [FR] +

The invention relates to a frothing machine (1) for creating froth from a drink containing milk, said frothing machine comprising a container (2) for receiving the drink, a stirrer (3) to rotate inside the container (2), an element on which the stirrer (3) is mounted, driving means (5) arranged in such a way as to magnetically rotatably drive the stirrer (3), and means for holding the stirrer inside the container (2). Said holding means comprise at least one holding magnet fixed in relation to the container (2) in the operating position and are arranged in such a way as to ensure that the element is held magnetically inside the container (2). The invention can especially be used to create milk froth for producing drinks containing coffee and milk froth such as cappuccinos, café lattes, macchiatos etc.



HK1126637 (A1)

Device (1, 2) for frothing milk, comprising: - a main body (5), which main body forms a container (15) for the milk, a cover (7, 8) fitting onto the main body, and - agitation means (3) and drive means (4) for driving the agitation means, wherein the drive means are received at least partially in the cover, characterized in that - the device also comprises a base plate (12) provided with a first electric contact (21), - the main body is provided with a second electric contact (22), which second electric contact makes electrical contact with the first electric contact when the main body is placed on the base plate, the drive means are provided with a third electric contact (14), the main body is provided with a fourth electric contact (13), which fourth electric contact makes electrical contact with the third electric contact when the cover is placed on the main body, and the main body is provided with an electric conductor which forms an electrical connection between the second electric contact and the fourth electric contact.

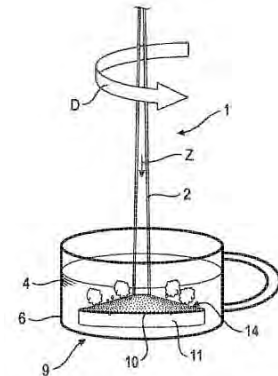


DE102007024443 (A1)

DE200710024443 20070525

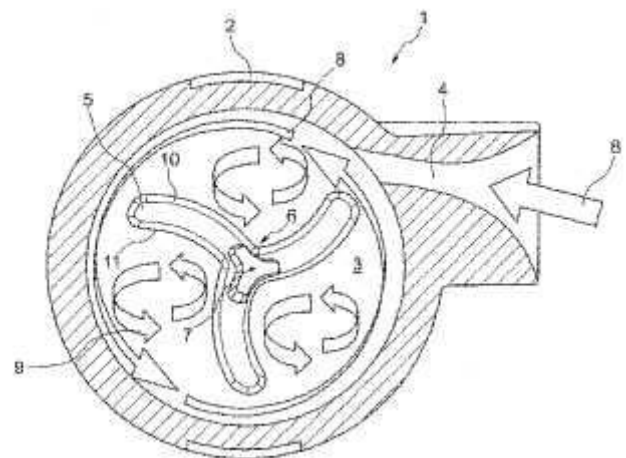
BSH BOSCH SIEMENS HAUSGERAETE [DE] +
2008-11-27

The method involves distributing a pressurized air stream in multiple partial streams. The partial streams are lead into milk (4). The milk is displaced in a movement vertical to the flow direction of the partial stream relative to the partial stream. The movement of the milk acts at the same time as the transport of the milk or the milk froth through a milk froth unit. The stream divider (10) is made of a porous material, which is a plastic, particularly polypropylene. An independent claim is also included for a milk froth device with a pressurized air inlet.



DE102008018007 (A1)

The device (1) has a housing (2) in which an emulsifying chamber (3) is provided, where the housing is designed as a plastic injection molding part. The emulsifying chamber is supplied with an air-milk-steam mixture by a supply channel (4) that tangentially joins in the chamber. A frothing body (6) is arranged centrally in the chamber. An axis (7) of the body is aligned transverse to a flow direction (8) of the air-milk-steam mixture. The frothing body has a radial blade (5) that is formed bent in a circumferential direction, where the supply channel is designed as a venturi-nozzle.

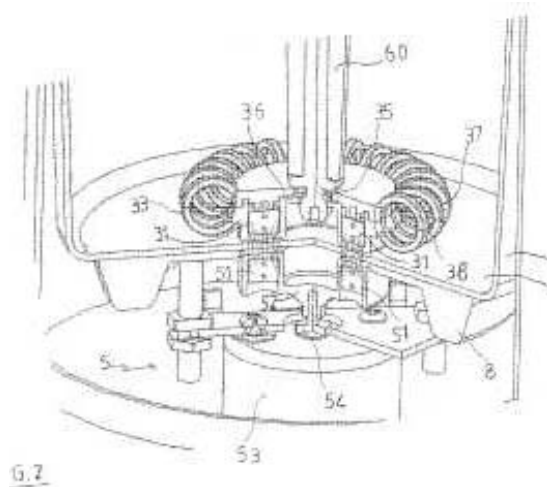


WO2009135758 (A1)

WO2009EP54772 20090422

CIE MEDITERRANEENNE DES CAFES [FR]; BLANC JEAN-PIERRE [FR]; GOERING ALAIN [FR] + (COMPAGNIE MEDITERRANEENNE DES CAFES, ; BLANC, JEAN-PIERRE, ; GOERING, ALAIN)

The invention relates to a frothing machine (1, 100) for creating froth from a drink containing milk, said frothing machine comprising a container (2) for receiving the drink, a stirrer (3) to rotate in the container (2) about a direction of rotation, and driving means (5) comprising at least one motor magnet (51) and arranged in such a way as to magnetically drive the stirrer about the direction of rotation. The stirrer (3) comprises a follower magnet (31) defining, with the motor magnet (51), a magnetic coupling and a gap within which the flux lines are essentially colinear to the direction of rotation. The invention can especially be used to create milk froth for producing drinks containing coffee and milk froth such as cappuccinos, café lattes, macchiatos etc.

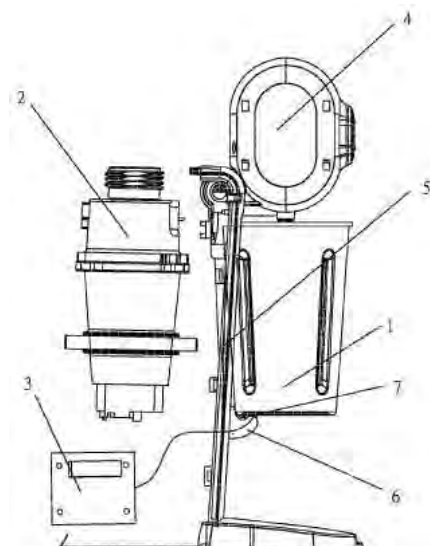


US2009255415 (A1)

US20090423785 20090414

TSANN KUEN CHINA ENTPR CO LTD [CN] + (TSANN KUEN(CHINA) ENTERPRISE CO., LTD)

A milk froth maker comprising a housing, a container, a heating unit and a control circuit unit mounted in said housing, and a stirring unit set at the top of the housing, said control circuit unit connected to the heating unit and the stirring unit respectively, a bracket unit for supporting the container arranged on the vertical board of the housing, and a temperature sensing unit set on the housing which temperature unit may or may not be in contact with the body of the container, wherein said temperature sensing unit can detect the temperature of the container and output the temperature signal to the control circuit unit for cutting off the power to said heating unit when the sensing signal of the temperature unit reaches a pre-set value.

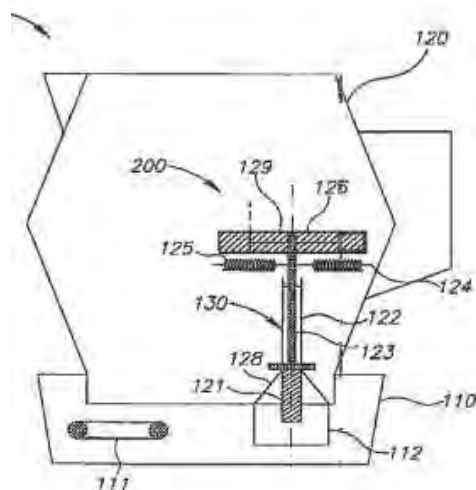


US2007133345 (A1)

US20060637248 20061212

Uppfinnare ZAROM RONY [US] +

the present invention provides an agitation device, comprising a motor for supplying rotational power, an outer shaft operatively connected to the motor, an extendible inner shaft positioned within the outer shaft and operatively connected thereto, an agitator positioned on the extendible inner shaft, and a floatation device positioned on the extendible inner shaft distal to the agitator from the motor for providing a buoyant force to the extendible inner shaft and the agitator for immersing the agitator at a predetermined level in a liquid. The present invention also provides a device for agitating and heating a liquid.

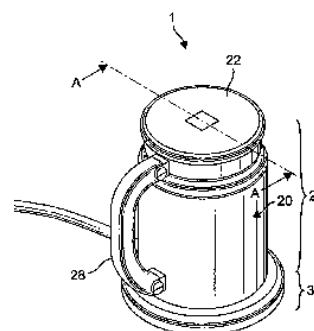


EP1656866 (A1)

EP20040026939 20041112

NESTEC SA [CH] +

The apparatus has a tank (21) to receive a milk-based liquid food with a magnetic beater (4). A magnetic beater driving system (5) produces a magnetic field which drives the beater in rotation in the tank. The system, beater and a beater positioning unit (6) break or prevent symmetrical circulation of the liquid around a median of vertical axis of the tank. Heating units are disposed in association with the tank for heating the liquid. An independent claim is also included for a method for preparing foam from a milk-based liquid food product.

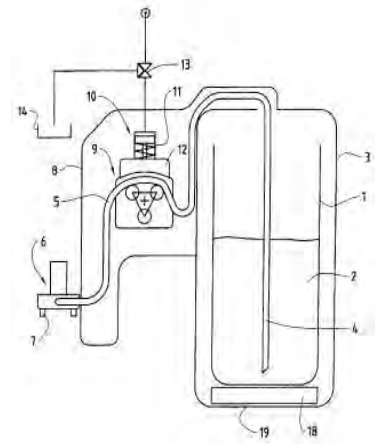


US2007031558 (A1)

US20050555120 20051101

SCHAERER AG M [CH] + (M. SCHAERER A.G. ; M. SCHAERER AG)

In a device for dispensing milk and/or milk froth from a container (1) containing milk, this container is placed in a coolable cabinet (3). Via an extraction line (4) and a further line (5), the milk reaches an emulsifying device (6) disposed outside the coolable cabinet. The product received is dispensed from this emulsifying device (6) via the discharge nozzle (7). Steam is feedable into the emulsifying device (6) with which steam the milk conducted through the emulsifying device (6) is able to be heated up and/or frothed up. The further line (5) consists of a flexible tube which is placed in a peristaltic pump (9). This peristaltic pump (9) is equipped with switching means (10) with which the peristaltic pump (9) is switchable from a closed pump state into an open pump state releasing the passage of the flexible tube (5). Milk of different temperatures or milk froth can be optimally dispensed using this device; in addition an optimal cleaning can be carried out. This device is advantageously integrated into a coffee machine, making it possible to obtain automatically different types of coffee with added milk.

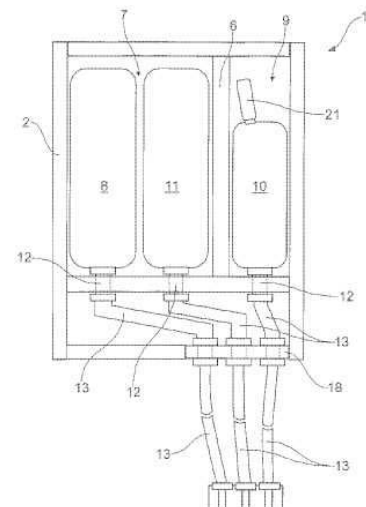


WO2006066633 (A1)

WO2005EP01946 20050224

MOBILESERVICE GMBH [CH]; RIETSCHER HANS-JOACHIM [DE] +

This invention relates to a milk froth/coffee beverage maker (1) which is designed independent from a maker-external energy supply and mobile. In a receiving holder (2), two replaceable and refillable liquid containers as coffee container (8) and milk container (10) are arranged thermally insulated from each other, each with a lower discharge opening in operating position, with an allocated container connection (12). Via tubes (13), the container connections (12) are connected with allocated manually operable tapping valves (14; 14') with tap openings. Moreover, a milk frothing means (21; 31) is allocated to the milk container (10), independent of a maker-external energy supply, wherein nitrous oxide (N₂O) as a foaming and expanding agent is introduced, preferably by means of a pressure cartridge, into the milk container (10).

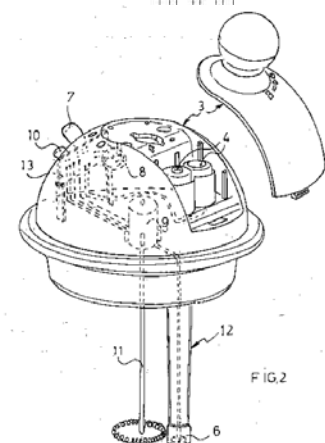


EP2153757 (A1)

EP20090009611 20090724

AXEL SRL [IT] +

The device, comprising a container (1) with handle (2) and a cover (3); consists of an electric circuit (5) fed through batteries (4), a thermal sensor (6) housing in a cylindrical protruding part (12), a switch (7) with three selection functions (7A, 7B, 7C), an acoustic signal (8), a motor (9) connected with a whisk (11) and a push-button (10).

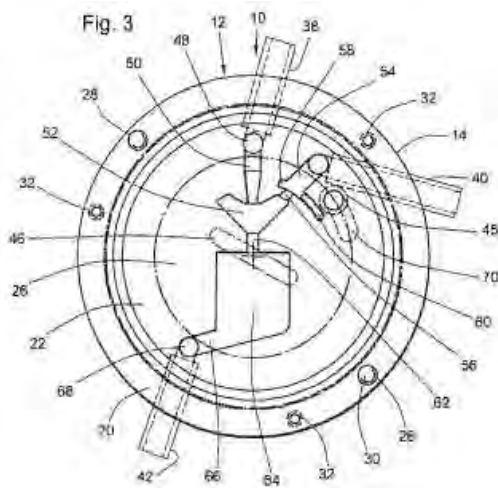


EP1857028 (A1)

EP20070108200 20070515

BSH BOSCH SIEMENS HAUSGERAETE [DE] +

The device (10) has housing (12). A froth chamber is provided, in which a water vapor line (38) opens out. A milk line (40) is provided, which discharges in front of froth chamber into the water vapor line. A mixing chamber is arranged at an inlet of the milk line leading into the water vapor line and outlet of the mixing chamber opens out into the froth chamber. A delivery pipe (42) is provided for milk froth from the froth chamber. The housing has two shell halves (14,16), which are detachably connected to each other.

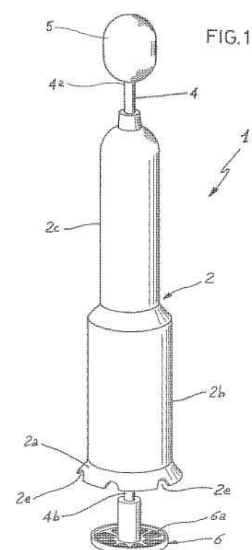


EP0875190 (A1)

EP19970830205 19970430

FRABOSK CASALINGHI SPA [IT] +

A froth making device for milk-based beverages, in particular cappuccino and the like, is provided which comprises a support and guide element (2), a piston-shaped emulsifying element (6), and an actuating rod (4) having a longitudinal extension adapted to dispose the piston element (6) to an end position substantially external to the support and guide element. Also provided is a froth making method for milk-based beverages, in particular cappuccino and the like, consisting in laying a supporting portion (9) of the device on the rim of a vessel directly used for taking the beverage to the consumer's mouth and operating a beating unit (3).

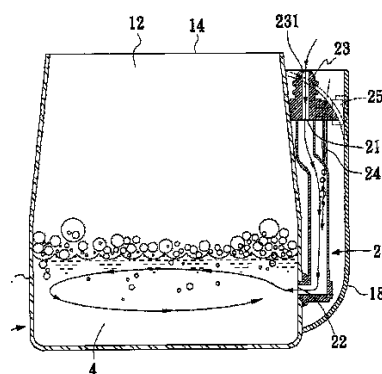


CN201332961 (Y)

CN20082183254U 20081223

GUOZHONG CHENG [CN] +

The utility model discloses a container for making and heating milk foam. The container comprises a steam guide pipe which is combined in the selected part of the container; a steam inlet is formed at one end of the steam guide pipe and positioned outside the container; a steam outlet is formed at the other end of the steam guide pipe and is positioned at the bottom part in the container or near to the bottom part; a forking air pipe is combined at the selected part of the steam guide pipe; and the air pipe is provided with an air valve. Therefore, by the container for making and heating milk foam, the steam inlet of the steam guide pipe is combined with a steam pipe of a steam producer or a coffee machine, steam enters the container to be mixed with liquid or fresh milk through the steam guide pipe, and further, the air valve is controlled to heat the liquid or make the dense milk foam in the container for being drunk or making coffee.



Appendix J: General survey

1. Gender

- ☐ Male
- ☐ Female

2. What country are you from?

3. How old are you?

- ☐ 15-23
- ☐ 23-35
- ☐ 35-60
- ☐ 60-

4. When you drink coffee do you use to have coffee with milk froth, for example cappuccino or cafe latte?

- ☐ Always
- ☐ Most of the times
- ☐ Rarely
- ☐ Never

5. If rarely or never, why?

- ☐ Takes to long time to prepare the milk froth
- ☐ Prefer coffee without milk froth
- ☐ Do not have a milk frother

6. What kind of milk froth is your favourite?

- ☐ Creamy froth, the foam is not hard, it is liquid and blends easily with the coffee.
- ☐ Hard froth, the froth is hard and lays like a lid on the coffee.
- ☐ Other

Other (please specify)

7. Rank the importance of these characteristics, regarding a milk frother.

	Desirable 10	9	8	7	6	5	4	3	2	Less desirable 1
Makes milk froth with a desirable texture	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Makes Natural milk froth without adding extra ingredients.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The level of sound	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Not to expensive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is environmental sustainable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Safe to use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Durable, gives a feeling of quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The colour	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Self-acting, little need of handle it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Easy to clean	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Makes tasty milk froth	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Appealing design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Convenient, easy to use and understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stand alone solution (no extra kitchen wear needed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has different functions for example cold or hot froth and can also heat milk without frothing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Makes milk froth quick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify and rank by putting a number here)	<input type="text"/>									

8. What kind of milk do you prefer to use when making milk froth?

- ☐ Milk with 3,0% fat (high-fat milk)
- ☐ Milk with 1,5% fat (medium-fat milk)
- ☐ Milk with 0,5% fat (low-fat milk)
- ☐ Milk with 0,1% fat (low-fat milk)
- ☐ Barista milk/Latte art milk or similar
- ☐ Barista milk/Latte art milk or similar, low-fat
- ☐ Other

Other (please specify)

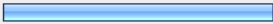
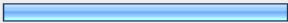
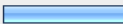


9. Where do you use to drink your coffee?

	Often 4	3	2	Not so often 1
On your way	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
At home	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
At work/school	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
At a café	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify and rank by putting a number here)

10. If you have anything on your mind regarding milk frothers, how you want it to look, perform, functions and so on, please write it here.

Appendix K: General survey answers

7. Rank the importance of these characteristics, regarding a milk frother.												
	Desirable 10	9	8	7	6	5	4	3	2	Less desirable 1	Rating Average	Response Count
Convenient, easy to use and understand	23.4% (11)	19.1% (9)	23.4% (11)	14.9% (7)	8.5% (4)	0.0% (0)	4.3% (2)	0.0% (0)	0.0% (0)	6.4% (3)	13.45	47
Makes milk froth quick	14.9% (7)	14.9% (7)	29.8% (14)	14.9% (7)	12.8% (6)	6.4% (3)	2.1% (1)	0.0% (0)	0.0% (0)	4.3% (2)	12.94	47
Makes tasty milk froth	42.6% (20)	14.9% (7)	23.4% (11)	6.4% (3)	6.4% (3)	0.0% (0)	0.0% (0)	2.1% (1)	0.0% (0)	4.3% (2)	14.81	47
Makes milk froth with a desirable texture	23.4% (11)	12.8% (6)	23.4% (11)	6.4% (3)	19.1% (9)	2.1% (1)	4.3% (2)	4.3% (2)	0.0% (0)	4.3% (2)	12.81	47
Makes Natural milk froth without adding extra ingredients.	44.7% (21)	23.4% (11)	10.6% (5)	0.0% (0)	8.5% (4)	4.3% (2)	2.1% (1)	2.1% (1)	0.0% (0)	4.3% (2)	14.68	47
Has different functions for example cold or hot froth and can also heat milk without frothing	4.3% (2)	2.1% (1)	21.3% (10)	12.8% (6)	10.6% (5)	8.5% (4)	8.5% (4)	14.9% (7)	6.4% (3)	10.6% (5)	8.60	47
Appealing design	14.9% (7)	8.5% (4)	23.4% (11)	19.1% (9)	21.3% (10)	4.3% (2)	0.0% (0)	2.1% (1)	4.3% (2)	2.1% (1)	12.26	47
Easy to clean	52.2% (24)	15.2% (7)	19.6% (9)	6.5% (3)	2.2% (1)	2.2% (1)	0.0% (0)	0.0% (0)	0.0% (0)	2.2% (1)	15.74	46
Stand alone solution (no extra kitchen wear needed)	29.8% (14)	8.5% (4)	25.5% (12)	12.8% (6)	4.3% (2)	6.4% (3)	6.4% (3)	0.0% (0)	0.0% (0)	6.4% (3)	13.15	47
Is environmental sustainable	4.3% (2)	15.2% (7)	26.1% (12)	19.6% (9)	13.0% (6)	6.5% (3)	6.5% (3)	2.2% (1)	2.2% (1)	4.3% (2)	11.57	46
The colour	4.3% (2)	4.3% (2)	6.4% (3)	14.9% (7)	23.4% (11)	12.8% (6)	12.8% (6)	0.0% (0)	2.1% (1)	19.1% (9)	8.30	47
The level of sound	12.8% (6)	12.8% (6)	10.6% (5)	25.5% (12)	12.8% (6)	2.1% (1)	10.6% (5)	8.5% (4)	2.1% (1)	2.1% (1)	11.36	47
Durable, gives a feeling of quality	14.9% (7)	31.9% (15)	17.0% (8)	12.8% (6)	10.6% (5)	4.3% (2)	2.1% (1)	2.1% (1)	0.0% (0)	4.3% (2)	13.32	47
Not too expensive	14.9% (7)	19.1% (9)	27.7% (13)	14.9% (7)	12.8% (6)	4.3% (2)	4.3% (2)	0.0% (0)	0.0% (0)	2.1% (1)	13.28	47
Self-acting, little need of handle it	6.4% (3)	14.9% (7)	23.4% (11)	12.8% (6)	14.9% (7)	12.8% (6)	8.5% (4)	2.1% (1)	0.0% (0)	4.3% (2)	11.45	47
Safe to use	23.9% (11)	10.9% (5)	15.2% (7)	19.6% (9)	8.7% (4)	10.9% (5)	2.2% (1)	0.0% (0)	2.2% (1)	6.5% (3)	12.43	46
Other												
Alternative tastes (like sugar) 10												
8. What kind of milk do you prefer to use when making milk froth?												
Milk with 3,0% fat (high-fat milk)											38.3%	18
Milk with 1,5% fat (medium-fat milk)											40.4%	19
Milk with 0,5% fat (low-fat milk)											17.0%	8
Milk with 0,1% fat (low-fat milk)											0.0%	0
Barista milk/Latte art milk or similar											12.8%	6
Barista milk/Latte art milk or similar, low-fat											0.0%	0
Other											6.4%	3

9. Where do you use to drink your coffee?						
	Often 4	3	2	Not so often 1	Rating Average	Response Count
At home	34.2% (13)	31.6% (12)	26.3% (10)	7.9% (3)	2.92	38
At a café	0.0% (0)	20.5% (8)	53.8% (21)	25.6% (10)	1.95	39
At work/school	69.2% (27)	20.5% (8)	7.7% (3)	2.6% (1)	3.56	39
On your way	2.8% (1)	13.9% (5)	13.9% (5)	69.4% (25)	1.50	36
10. If you have anything on your mind regarding milk frothers, how you want it to look, perform, functions and so on, please write it here. Hate it when they have a long "warm up" time. Would like to make the froth as it is in a cafe (barista, coffeemachine). Not spaceconsuming (easy to move and handle). Maybe include a little book of frothing art, or a forhting tutorial of nice patterns or figures. Be able to wash in a dishwasher.						

Appendix L: Kano survey

1. <--If the milk frother prepares a tasty milk froth, how do you feel?

If the milk frother do NOT prepare a tasty milk froth, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

2. <--If the milk frother prepares milk froth that has a desirable texture, how do you feel?

If the milk frother do NOT prepare milk froth that has a desirable texture, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

3. <--If the milk frother is convenient and easy to use, how do you feel?

If the milk frother is NOT convenient and easy to use , how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

4. <--If the milk frother is easy to clean, how do you feel?

If the milk frother is NOT easy to clean, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

5. <--If the milk frother is environmental sustainable, how do you feel?

If the milk frother is NOT environmental sustainable, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

6. <--If the milk frother is appealing, how do you feel?

If the milk frother is NOT appealing, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

7. <--If it is quick to prepare the milk froth, how do you feel

If it is NOT quick to prepare the milk froth, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

8. <--If the milk frother can be used without any other kitchen wear, how do you feel?

If the milk frother can NOT be used without any other kitchen wear, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

9. <--If the milk frother have different functions for example cold or hot froth, how do you feel?

If the milk frother do NOT have different functions, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

☐ (N) I am NEUTRAL

☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

☐ (D) I am DISSATISFIED when it is like that

10. <--If the milk frother add a substance to make the froth better, how do you feel?

If the milk frother makes milk froth without adding a substance, how do you feel?-->

☐ (S) I am SATISFIED when it is like that

☐ (S) I am SATISFIED when it is like that

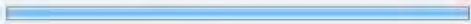











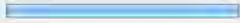

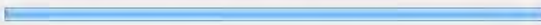


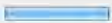

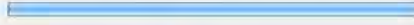
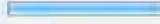

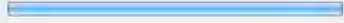

☐ (N) I am NEUTRAL




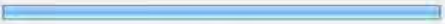


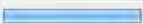


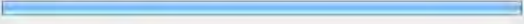
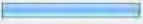

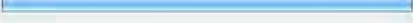
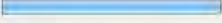
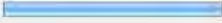
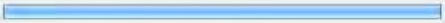



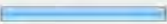

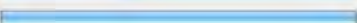


☐ (N) I am NEUTRAL

☐ (D) I am DISSATISFIED when it is like that

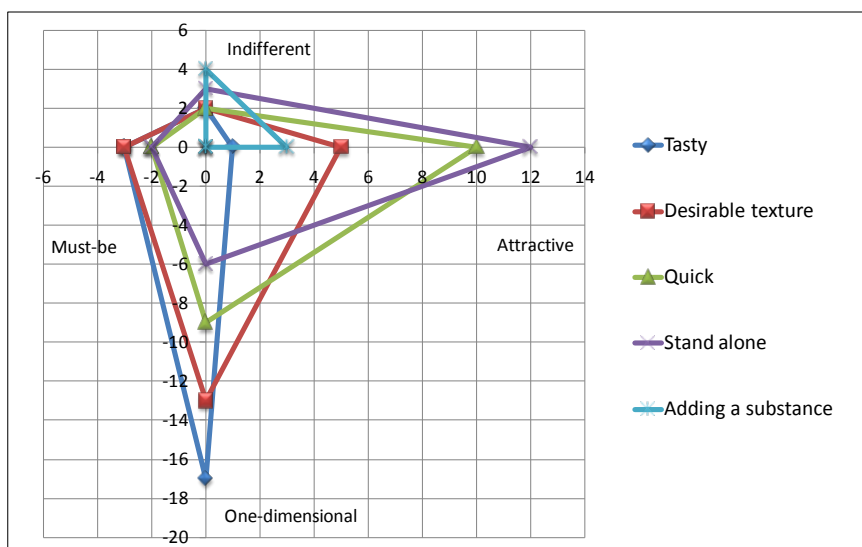
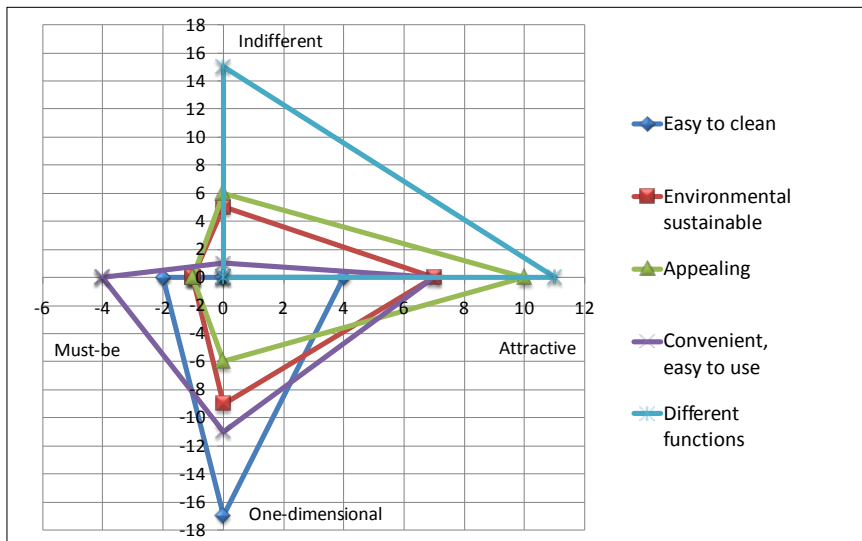
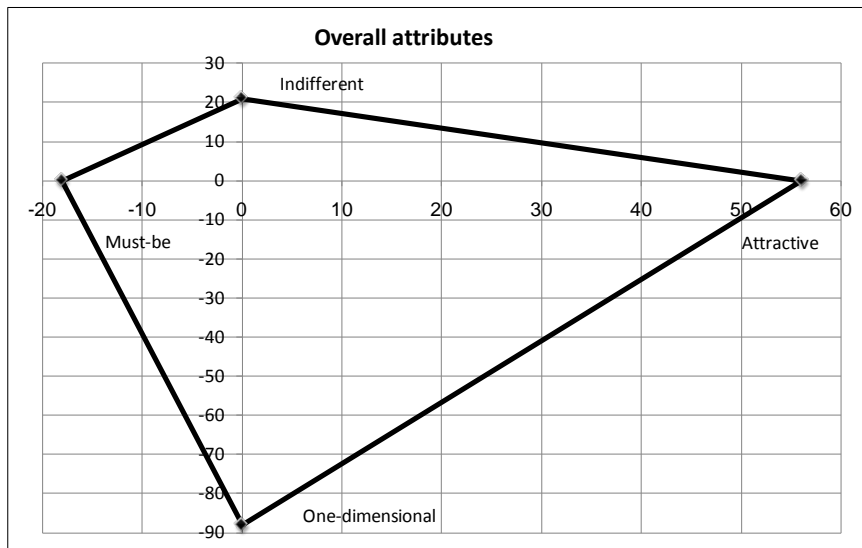
☐ (D) I am DISSATISFIED when it is like that

Appendix M: Kano survey answers

1. <--If the milk frother prepares a tasty milk froth, how do you feel? If the milk frother do NOT prepare a tasty milk froth, how do you feel?-->		Response Percent	Response Count
(S) I am SATISFIED when it is like that		75.0%	18
(N) I am NEUTRAL		25.0%	6
(D) I am DISSATISFIED when it is like that		0.0%	0
(S) I am SATISFIED when it is like that		4.2%	1
(N) I am NEUTRAL		12.5%	3
(D) I am DISSATISFIED when it is like that		83.3%	20
2. <--If the milk frother prepares milk froth that has a desirable texture, how do you feel? If the milk frother do NOT prepare milk froth that has a desirable texture, how do you feel?-->			
(S) I am SATISFIED when it is like that		79.2%	19
(N) I am NEUTRAL		20.8%	5
(D) I am DISSATISFIED when it is like that		0.0%	0
(S) I am SATISFIED when it is like that		0.0%	0
(N) I am NEUTRAL		37.5%	9
(D) I am DISSATISFIED when it is like that		66.7%	16
3. <--If the milk frother is convenient and easy to use, how do you feel? If the milk frother is NOT convenient and easy to use, how do you feel?-->			
(S) I am SATISFIED when it is like that		75.0%	18
(N) I am NEUTRAL		20.8%	5
(D) I am DISSATISFIED when it is like that		4.2%	1
(S) I am SATISFIED when it is like that		0.0%	0
(N) I am NEUTRAL		37.5%	9
(D) I am DISSATISFIED when it is like that		62.5%	15
4. <--If the milk frother is easy to clean, how do you feel? If the milk frother is NOT easy to clean, how do you feel?-->			
(S) I am SATISFIED when it is like that		87.5%	21
(N) I am NEUTRAL		8.3%	2
(D) I am DISSATISFIED when it is like that		4.2%	1
(S) I am SATISFIED when it is like that		0.0%	0
(N) I am NEUTRAL		16.7%	4
(D) I am DISSATISFIED when it is like that		83.3%	20
5. <--If the milk frother is environmental sustainable, how do you feel? If the milk frother is NOT environmental sustainable, how do you feel?-->			
(S) I am SATISFIED when it is like that		66.7%	16
(N) I am NEUTRAL		25.0%	6
(D) I am DISSATISFIED when it is like that		8.3%	2
(S) I am SATISFIED when it is like that		0.0%	0
(N) I am NEUTRAL		54.2%	13
(D) I am DISSATISFIED when it is like that		45.8%	11

6. <--If the milk frother is appealing, how do you feel? If the milk frother is NOT appealing, how do you feel?-->			
(S) I am SATISFIED when it is like that		70.8%	17
(N) I am NEUTRAL		29.2%	7
(D) I am DISSATISFIED when it is like that		0.0%	0
(S) I am SATISFIED when it is like that		4.2%	1
(N) I am NEUTRAL		66.7%	16
(D) I am DISSATISFIED when it is like that		29.2%	7
7. <--If it is quick to prepare the milk froth, how do you feel if it is NOT quick to prepare the milk froth, how do you feel?-->			
(S) I am SATISFIED when it is like that		79.2%	19
(N) I am NEUTRAL		20.8%	5
(D) I am DISSATISFIED when it is like that		0.0%	0
(S) I am SATISFIED when it is like that		0.0%	0
(N) I am NEUTRAL		50.0%	12
(D) I am DISSATISFIED when it is like that		50.0%	12
8. <--If the milk frother can be used without any other kitchen wear, how do you feel? If the milk frother can NOT be used without any other kitchen wear, how do you feel?-->			
(S) I am SATISFIED when it is like that		79.2%	19
(N) I am NEUTRAL		20.8%	5
(D) I am DISSATISFIED when it is like that		0.0%	0
(S) I am SATISFIED when it is like that		4.2%	1
(N) I am NEUTRAL		62.5%	15
(D) I am DISSATISFIED when it is like that		33.3%	8
9. <--If the milk frother have different functions for example cold or hot froth, how do you feel? If the milk frother do NOT have different functions, how do you feel?-->			
(S) I am SATISFIED when it is like that		33.3%	8
(N) I am NEUTRAL		66.7%	16
(D) I am DISSATISFIED when it is like that		0.0%	0
(S) I am SATISFIED when it is like that		4.2%	1
(N) I am NEUTRAL		91.7%	22
(D) I am DISSATISFIED when it is like that		4.2%	1
10. <--If the milk frother add a substance to make the froth better, how do you feel? If the milk frother makes milk froth without adding a substance, how do you feel?-->			
(S) I am SATISFIED when it is like that		25.0%	6
(N) I am NEUTRAL		20.8%	5
(D) I am DISSATISFIED when it is like that		54.2%	13
(S) I am SATISFIED when it is like that		66.7%	16
(N) I am NEUTRAL		33.3%	8
(D) I am DISSATISFIED when it is like that		0.0%	0
answered question			24

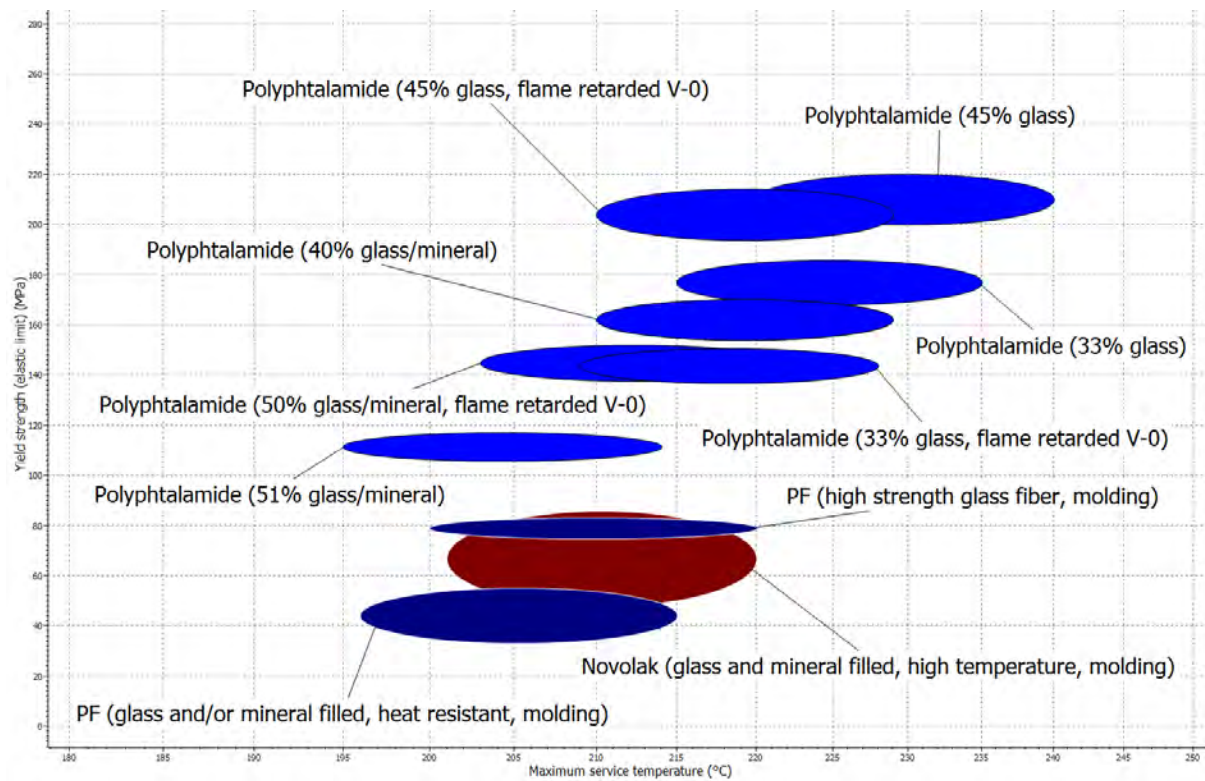
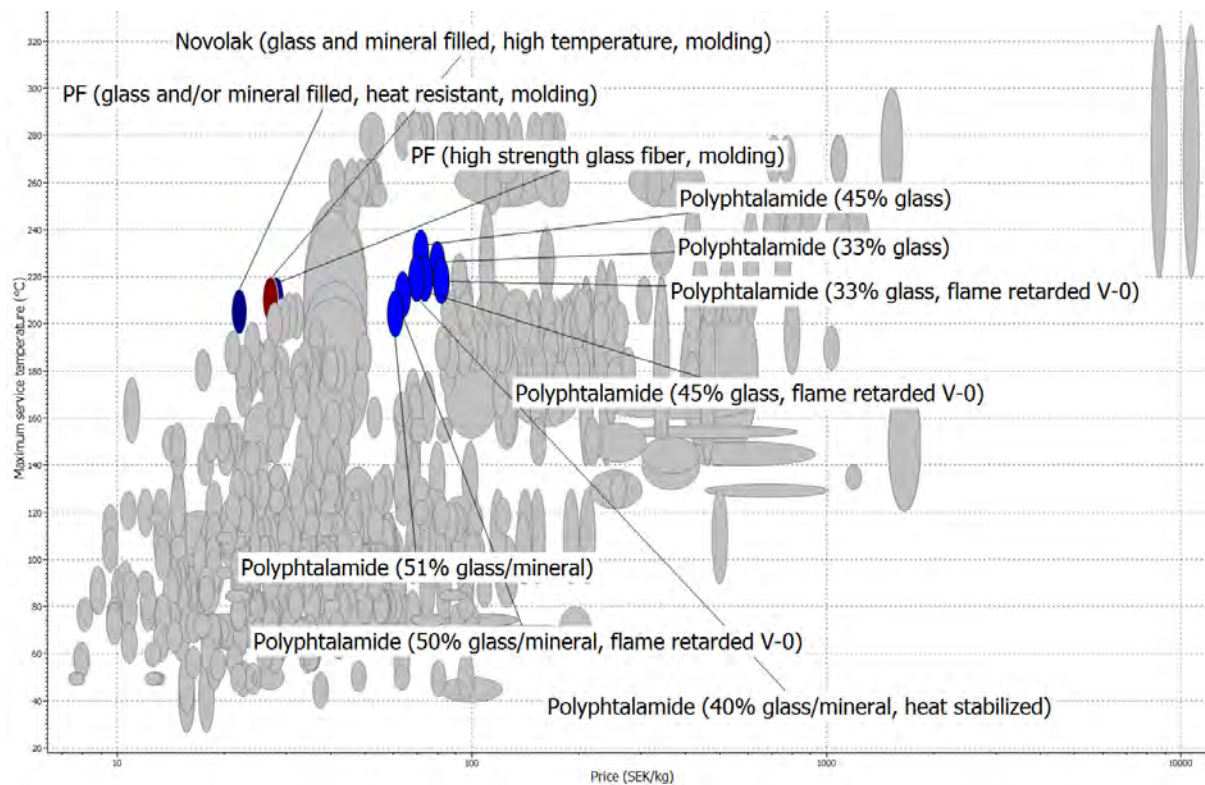
Appendix N: Kano diagrams



Customer Requirements		Dysfunctional		
		Dissatisfied	Neutral	Satisfied
Functional	Dissatisfied	Questionable	Reverse	Reverse
	Neutral	Must-be	Indifferent	Reverse
	Satisfied	One-dimensional	Attractive	Questionable

Customer Requirements	Attractive	Must-Be	One-Dimensional	Reverse	Questionable	Indifferent	Grade
Tasty	1	3	17	0	0	2	One-Dimensional
Desirable texture	5	3	13	0	0	2	One-Dimensional
Convenient, easy to use	7	4	11	0	0	1	One-Dimensional
Easy to clean	4	2	17	0	0	0	One-Dimensional
Environmental sustainable	7	1	9	1	0	5	One-Dimensional
Appealing	10	1	6	0	0	6	Attractive
Quick	10	2	9	0	0	2	Attractive
Stand alone	12	2	6	0	0	3	Attractive
Different functions	7	1	0	0	0	15	Indifferent
Adding a substance	3	0	0	16	0	4	Reverse

Appendix O: Rough material scan



Interesting materials placed in a yield strength-maximum service temperature diagram

[illegible]

[REDACTED]
 [REDACTED]
 [REDACTED]
 [REDACTED]
 [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

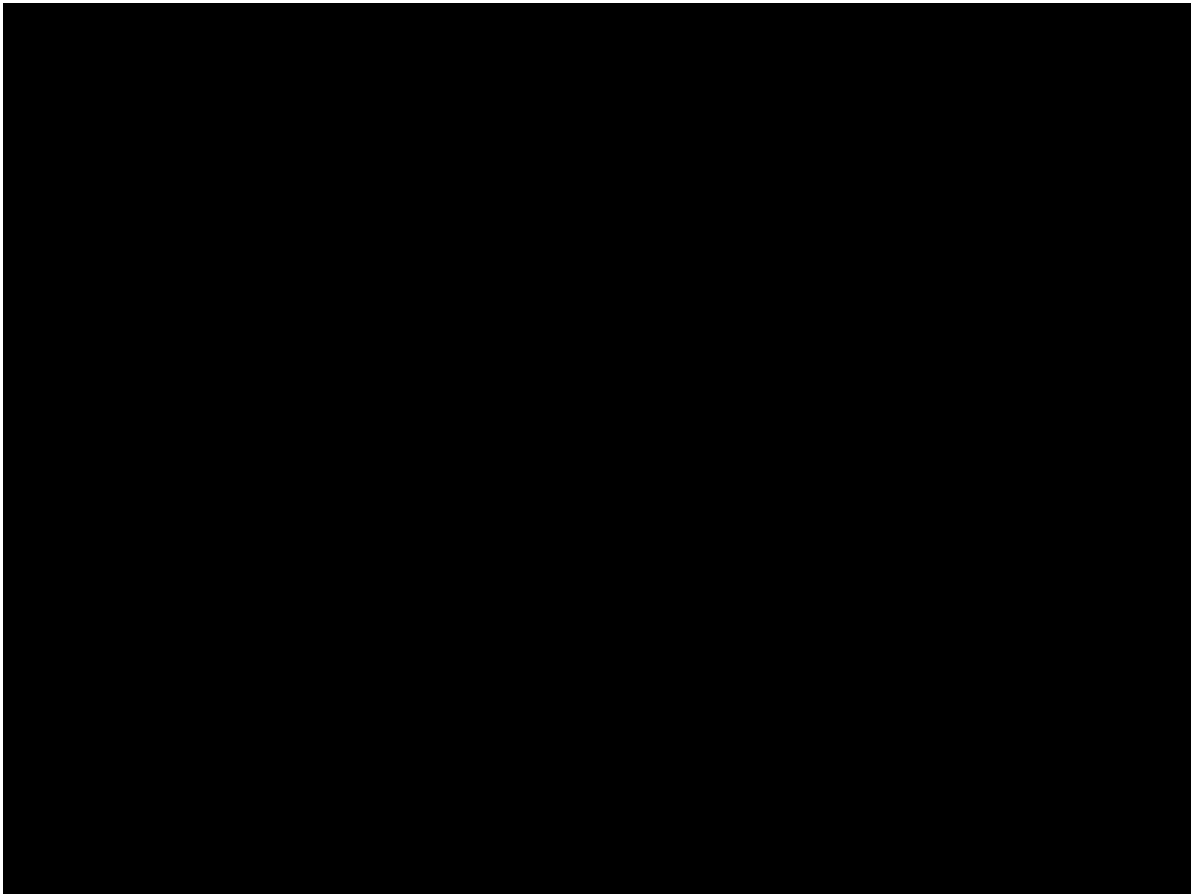
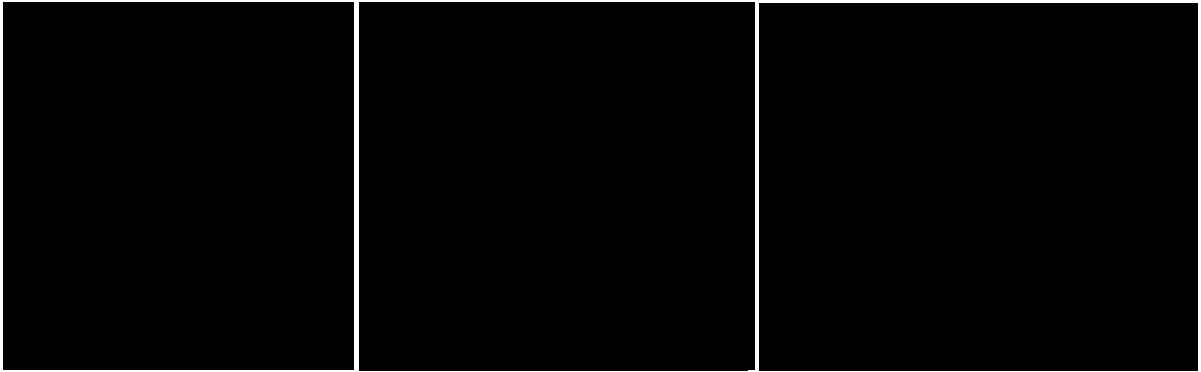
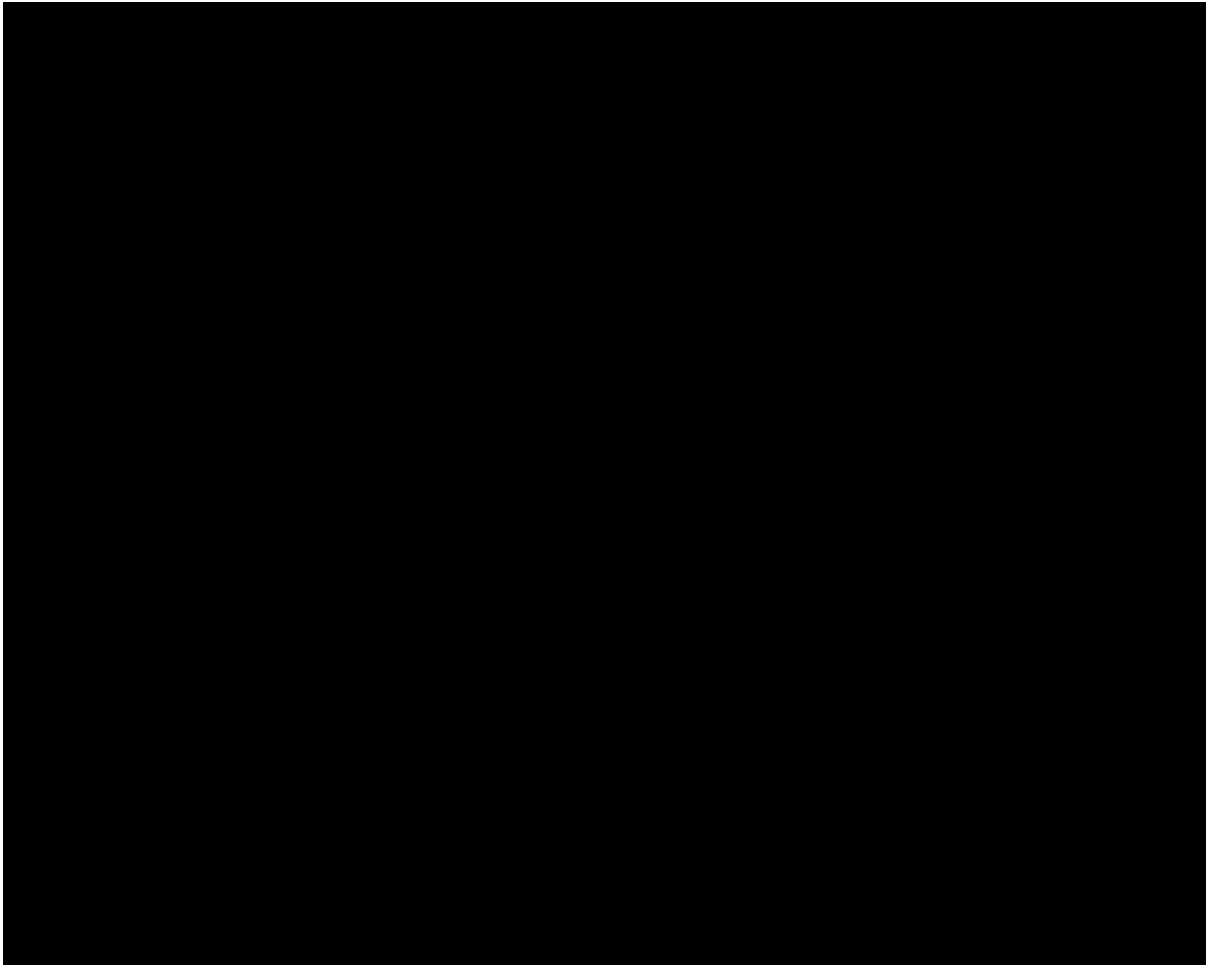


Plate where the motor and gear wheel is mounted

[REDACTED]

[REDACTED]



[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

Appendix R: Electric scheme

