HACCP project on toffee ice cream production

Andreas Carlsson
Food microbiology
Swedish University of Agricultural Sciences, Uppsala
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Introduction

In this report a small HACCP study will be performed for the making of an ice cream product. The concept of HACCP will get a brief presentation, as well as how the production is run. Then the HACCP study is presented.

The toffee ice cream (*gräddkola*), which is the subject of the study, is an ice cream product of SIA Glass AB, which has produced ice cream in western Sweden since 1961. The product is sold in 1.5-liter packs. The same flavour occurs in ice cream for scooping at vendors, but then the proportions in the recipe is altered.

The report is the result of a project work in a course in food microbiology in the Swedish University of Agricultural Sciences in Uppsala. It will give a general picture of the health hazards that could be associated with ice cream making, and give an idea on what conclusions a HACCP study for this production could result in. When making an actual HACCP study many more hazards are discussed, so the scope of this report is limited. Another limitation is that the production plant has not been visited, which must be done in performing a HACCP study.

Ice cream history

The history of ice cream is described differently depending on source. The description as follows is the one presented by Börzsei (2005).

The first ice cream was probably sorbet made in China, 5000 years ago. Ice cream making, as well as the technique to keep it cold with ice and salt, spread through Asia and found its way to Europe. In Italy, the sorbet was further developed and also was the place for inventing "real" ice cream, i.e. made from cream. In the 17th century Louis XIV of France had ice cream as his favourite dessert and his chef was the first to make vanilla and chocolate ice cream.

In Sweden ice cream had found its way into cookbooks during the 18th century, and was introduced further by Italian immigrants during the 19th century. Though, some people believed ice cream was dangerous and could be lethal. This attitude persisted until the beginning of the last century. The Swedish ice cream industry started in the 1930s and ice cream got its big breakthrough in 1955, when there was an economic boom, a warm summer and doctors had accepted ice cream as a fully adequate and nutritious dairy product. At present about 15 litres of ice cream per person is consumed in Sweden each year.

Background on HACCP

Since 1 January 2006 there is a new food legislation in the EC. This requires that all food companies along the food chains (except for primary production) apply the HACCP concept, which was already a legal requirement in a number of other countries. HACCP stands for Hazard Analysis Critical Control Points and is the most efficient system for the production of safe food.

Before HACCP can be introduced for a process, some prerequisites have to be in place. These are the good hygiene practices (GHP), for example hygienic routines for the personnel, maintenance, waste management, personnel education, cleaning and disinfection routines, and so on. Without these HACCP is of no use. When a company introduces the concept of HACCP it should have full support from the company management. The team, which will perform the HACCP study, should be multidisciplinary and include persons working with areas such as production, quality management, engineering and microbiology. All should have been taught in the principles of the concept.

The seven HACCP principles are hazard analysis, identifying critical control points, critical limits, monitoring, corrective actions, verification and documentation.

- **Hazard analysis** is a key part of the HACCP study. When performing a hazard analysis, agents posing a possible health threat are identified. The different hazards are then evaluated to assess the severity and risk. Only significant hazards will be addressed, and preventative measures have to be found for these hazards.
- **Identifying of critical control points:** A critical control point (CCP) is a step in the production process, in which a hazard can be controlled. Each hazard must be controlled in a CCP, which for instance could be a pasteurization step.
- **Critical limits** are then set for the CCP. If a limit is not met, for example a temperature limit, the process is not sufficient to produce a safe product.
- **Procedures for monitoring** the critical limits are then implemented. When the critical limit is a temperature, the monitoring could be performed with a continuously measuring thermometer.
- **Corrective actions** are to be taken if the monitoring system reports that a critical limit is not met. Actions must be defined for each CCP in the HACCP plan. A corrective action could be destroying product produced during the incorrect process.
- **Verification procedures** are used for evaluating the process, to make sure that everything complies with the HACCP plan.
- **Documentation** must be kept for all work regarding HACCP.

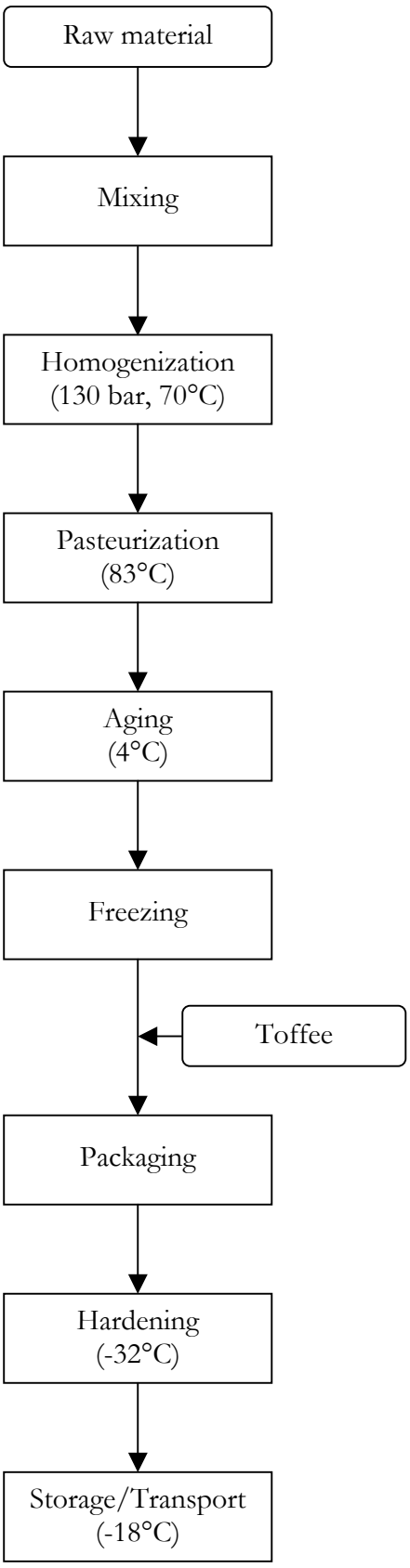
Production process

The production process for making toffee ice cream (*gräddkola*) is quite typical for ice cream, with mixing of the ingredients, homogenization, pasteurization, aging, freezing, toffee addition, packaging and hardening. Information on the process has been recieved from Peder Roslyng, SIA Glass AB.

The toffee ice cream is made of various ingredients (figure below). The "butter English toffee" is bought from a supplier, and added late in the process. All other ingredients are mixed in the beginning of the process. Then the mixture is heated to 60°C before homogenization at 70°C and 130 bar. Pasteurization is performed at 83°C for about 20 seconds, and then the ice cream mix is chilled to 4°C. The aging step at this temperature lasts for 12–24 hours. Then the ice cream mix is frozen to -5°C, whereafter the toffee is added. At -5°C the ice cream is still soft, so it can be filled into plastic packs. The ice cream is quickly hardened in a tunnel at -32°C. The finished product is stored at least at -18°C, before transportation in freezer trucks.

Ingredients

- Milk
- Cream
- "Butter English toffee"
  - Sugar
  - Glucose syrup
  - Almond
  - Butter
  - Vegetable fat
  - Salt
  - Sodium carbonates
  - Soy lecithin
- Glucose syrup
- Dextrose
- Sugar
- Whey powder
- Aroma
- Emulsifier
- Stabilizer



Hazard analysis

Ice cream is a medium, which could support microbiological growth; it is nutritious and has pH 6–7 (HKSAR Government, 2001). Since it is pasteurized and frozen, the microbial concern is decreased. There are a couple of possible hazards, which could be associated with ice cream. The National Food Administration (2006) mentions *Bacillus cereus*, *Listeria monocytogenes* and allergens as examples of hazards with ice cream. *Salmonella* spp. could be a problem in products with egg, but the ice cream studied in this report does not contain egg. Though, it contains milk, cream and whey powder, so there is still some risk for *Salmonella*.

If psychrotrophs would get the chance to contaminate the ice cream they would not grow when the temperature is -18°C. Though, during the aging step in the production process, the temperature would be more favourable (4°C). Even if their growth would stop due to freezing or pasteurization, some of their enzymes would persist. This is the reason that ice cream made from milk, even milk powder, may become rancid due to fat degradation (Lindgren, 2006). Although this effect is negative for the consumer, it does not pose a health risk.

There are a number of incidents that could be hazardous when it comes to food safety. Insects, birds and other organisms may find their way into the production facility. These may contaminate the ice cream and spread disease. Though, this can be subjected in the routines included in GHP.

When considering whether or not to address the problem of a hazard in the HACCP plan, one has to consider how serious the hazard is and how often the hazard occurs. Now follows a discussion and description of a number of pathogens, mycotoxins and shortly about allergens, which could pose as hazards in the ice cream making. Focus is put on hazards of microbiological origin. If nothing else is mentioned, the information in the three following sections, concerning micro-organisms, is taken from Adams and Moss (2000).

Bacillus cereus

Bacillus cereus is a facultatively anaerobic, gram-positive, spore forming bacterium. Growth occurs between 8 and 55°C. It is common and widely spread in the environment and is found in soil, water and on vegetation. It can also be present in the human gut flora.

Due to the ability to form spores and the fact that it is present almost everywhere, *B. cereus* is difficult to get hold of in the food industry. In milk products, like the toffee ice cream, the organism may enter for example through contamination at the milking. Psychrotrophic strains of *B. cereus* cause spoilage in milk, especially during summer when the cows are grazing in the pastures (Jonsson, 2006; Öhman, 2006). During handling of the milk, *B. cereus* can grow if the temperature gets high enough, but at pasteurization temperature vegetative cells die. However, spores may survive and germinate when the temperature is lowered. Since gram-positives generally have a higher tolerance to freezing, in addition to freezing and pasteurization resistance among spores, *B. cereus* can be suspected to be of concern in ice cream.

There are two types of food poisoning caused by *B. cereus*. The diarrhoeal syndrome is an attack from vegetative cells producing enterotoxin in the intestine. This leads to abdominal pain and watery diarrhoea for 12 to 24 hours. The emetic syndrome is caused by enterotoxin produced by cells in the foodstuff, before ingestion. It has a shorter incubation time than the diarrhoeal syndrome. The symptoms resemble *Staphylococcus aureus* food poisoning (nausea, vomiting, stomach cramps and diarrhoea) and last for 6 to 24 hours.

B. cereus does not cause any serious disease. It is uncomfortable, but it is not lethal and does not have chronic effects. Though, it is a spore forming pathogen that is present almost everywhere. When taking this into account it is reasonable to address this pathogen in the HACCP plan. Illness is rarely coupled to *B. cereus* in dairy products, which may be due to that the milk is unfavourable to toxin formation. Spores are not dangerous to eat, so ungerminated spores are not hazardous in the product. As long as vegetative cells are few there is little risk of problems. For an outbreak to occur there will be more than 10^5 bacteria per gram food. The target in the HACCP plan will be to eliminate vegetative cells, which is done with pasteurization.

Listeria monocytogenes

Listeria monocytogenes is, just like *B. cereus*, a gram-positive and facultatively anaerobic bacterium, but it does not form spores. It grows between 0 and 42°C, but very slowly at the lower temperatures. It is widespread and may be found in water, soil, sewage sludge and silage. Healthy humans may be carriers of the bacterium.

The prevalence of *L. monocytogenes* makes it easy for it to enter the food chain. Pasteurized milk has been the cause of a number of outbreaks of disease. The contamination of the milk could originate from dirty udders (Lindgren, 2006). Though, the D_{70} value is a few seconds, which could mean that the milk had been improperly handled at the dairy. In the worldwide perspective, *L. monocytogenes* in ice cream products is of significant food safety concern (HKSAR Government, 2001).

Infection caused by *L. monocytogenes* is not common. To get ill a person needs to be susceptible and be exposed to a sufficiently high dose of a virulent strain. The infective dose is over 10^2 cfu/g. Pregnant women, very young, elderly and immunocompromised people may get symptoms, which vary from flu-like to meningitis. Listeriosis may be deadly, and in pregnant women the disease may affect the foetus and result in abortion.

Persons from the susceptible groups are most likely consumers of the product. Since *L. monocytogenes* may result in death among the susceptible groups and it may enter the milk at milking, it must be taken into consideration as a hazard in the HACCP plan for a dairy product as the toffee ice cream. This is especially the case since the organism is known to be of safety concern in ice cream. The knowledge of that there has been outbreaks of listeriosis due to pasteurized milk tells us that there is a need for quality assurance. *L. monocytogenes* will be addressed as a hazard in the HACCP plan, and may be controlled by pasteurization.

Salmonella

Salmonella spp. is a gram-negative, facultatively anaerobic organism, which does not form spores. Growth occurs at 5–47°C, and the organism is heat sensitive. It is a zoonotic organism, which may be found in different animals' guts.

Because *Salmonella* may be found in animals, it has a good chance of contaminating foodstuff of animal origin, like meat, milk and egg. In for example Sweden and Finland there is zero-tolerance regarding *Salmonella* infection among domestic animals, which lowers the risk of human infection. Good handling and heat treatment of the food is necessary to decrease the risk. The use of raw egg in ice cream has been the cause of disease outbreaks.

Salmonella may cause either enteritis or a systemic infection. The gastro-intestinal infection has symptoms as milk fever, vomiting and diarrhoea lasting for a few days up to more than a week. The infectious dose is in the order of 10^6 cells, but in some cases it has been much lower than that. The systemic infection is caused by invasive, host-adapted serotypes. The bacteria then spread in the body and causes fever, headache and diarrhoea. *Salmonella* infection may be fatal.

The toffee ice cream does not contain egg, but milk, cream and whey powder are all of animal origin. These ingredients are Swedish, which lowers the risk of *Salmonella* infection. Of the ingredients, especially whey powder has been pointed out as a source of *Salmonella* (National Food Administration, 2006). Hence, there is a risk for *Salmonella* contamination in the product. Luckily the organism's heat sensitivity makes it possible to eliminate with pasteurization. The severity of the disease in combination with the risk makes *Salmonella* a hazard to target in the HACCP plan.

Mycotoxins

Mycotoxins are produced by mould, and there is a range of different compounds originating from different types of mould among the Deuteromycetes. The mycotoxins are secondary metabolites, toxic in low concentrations in vertebrates.

Aflatoxins are a group of mycotoxins produced by *Aspergillus flavus* and *Aspergillus parasiticus*. These may grow in nuts, dried fruit and infect stored cereal grains where they produce the aflatoxins. When such toxins are formed they do not go away. They are heat stable, and thus stay in the food along the food chain, unaffected by heat treatments as pasteurization. When a cow eats a feed contaminated with aflatoxin B_1, the activity of the cow changes the aflatoxin B_1 to aflatoxin M_1, which ends up in the milk (Johnsson, 2006). This leads to a concern for contamination of aflatoxin M_1 in ice cream.

The toxicity of aflatoxin is mainly due to its carcinogenicity. This is because aflatoxins are genotoxic, meaning it affects the genetic material. Genotoxins have a direct dose-response relationship, so they do not have a threshold dose to exceed before they have effect. Thus, there is no tolerable daily intake (TDI) for aflatoxins, which are to be kept at a level

as low as possible. Though, maximum levels are set in the European Union, for example 0.05 μg/kg of milk for aflatoxin M_1.

Mycotoxins in the product can only be prevented at the source where the mould infection occurs, since the toxins are impossible to remove. In the case of ice cream, control measures could be taken at the production and handling of cow's feed. An example of milk contaminated with aflatoxin is a case in southern Sweden, where a number of farms had problems with aflatoxin in the milk due to contaminated feed from a common supplier (Johnsson, 2006).

Except for the milk-based ingredients, the almond in the toffee could contain aflatoxin. Thus, there is a risk for getting the aflatoxins into the ice cream. Since aflatoxins have a cumulative negative effect in humans they should be considered as hazards in the HACCP plan.

Allergens

The ice cream contains ingredients that some people are allergic to. These allergens are milk (and cream), almond and soy lecithin. When such ingredients are used the product must be labelled. An allergic reaction is an abnormal response from the immune system. It attacks for example a food constituent as if it was a foreign body.

Since the mentioned ingredients are an inevitable part of the product, those allergic to them must be informed to prevent them from consuming it. This is achieved through labelling – clearly stating what allergens the product contains.

Other allergens are used in other products produced in the same process line, for example eggs and nuts. There is a risk for contamination of trace amounts of these allergens, and this must be avoided. Good routines for handling the allergens and for cleaning the equipment are needed. Such routines are not something to be taken up in the HACCP plan, but are instead necessary to treat within the GHP.

Summary

Here the hazards in toffee ice cream making are summarized in a table.

Step	Potential hazard	Justification	To be addressed?	Control measure
Addition of milk and cream	*Bacillus cereus*	Known to occur	Yes	Pasteurization, chilling
Addition of milk and cream	*Listeria monocytogenes*	Known to occur	Yes	Pasteurization
Addition of milk, cream and whey powder	*Salmonella*	Known to occur	Yes	Pasteurization
Addition of milk, cream and almond	Aflatoxin	Known to occur	Yes	Analysis by manufacturer
Addition of milk, cream, almond and soy lecithin	Ingredients are allergenic	Some people are allergic	Yes	Labelling
Whole process	Contamination with nuts and eggs	Some people are allergic	No	GHP

Critical control points

Every hazard found to be significant enough to be addressed in the HACCP plan has to be controlled in a CCP – a step essential to prevent that hazard. In this section the whole process is gone through to establish whether or not each step may be considered to be a CCP. Also, the critical limits, monitoring procedures and corrective actions are settled.

Raw materials

When raw materials arrive at the factory it is important that they have a good quality. This could be investigated with analysis of material from each delivery. Another way of making sure that the raw material is of good quality is to ensure that the supplier has a quality programme (their own HACCP plan) that works. This may be complemented with random sampling and analysis of deliveries.

The hazard, for which the raw material delivery is a CCP, is aflatoxin. Among the ingredients in the ice cream, there is a risk for contamination of milk, cream and almond. The almond is already in the toffee when it is used, so the raw material to be checked in this case is the toffee. For the mentioned ingredients the supplier's HACCP plan has to be reviewed. This plan must be found to be sufficient to reduce the hazard and sufficient to ensure enough analyses to be performed. The supplier should ensure good primary production and – in the case of almonds – proper storage. Documents have to be enclosed with each delivery to guarantee the safety of the material (it complies with the HACCP plan of the supplier). In this case the critical limit is that such documents exist. The monitoring procedure for this CCP is to control that the proper documents exist at each delivery. The corrective action to apply if the documents are absent is to send the material back to the supplier, and change supplier if the problem recurs.

Pasteurization

Pasteurization affects most of the hazards mentioned earlier. Vegetative cells of the different pathogens die when properly pasteurized. After this step there will be no more step able to efficiently reduce the amount of organisms, and therefore it will be crucial for quality. Pasteurization will be a CCP, for which critical limits now will be established.

When doing very rough calculations with values from Warth (1978) and Eckner (1992), the most heat resistant vegetative cells among the pathogens above are those of *Salmonella* (Seftenberg 775W, the most heat resistant salmonella). The D_{83} value (pasteurization temperature in the process is 83°C) for this organism would be less than 0.2 seconds. For the pasteurization in the ice cream production, which lasts for about 20 seconds, this organism would be reduced with 100 log cycles. Though, this would assume that the organisms were experiencing this temperature. An uneven temperature distribution would result in a lower reduction of organisms. Still, to make the product safe, this is probably more than necessary, so the pasteurization temperature and/or time may be decreased, though it may be needed for product quality reasons.

With the temperature and time figures being higher than needed, it is difficult to set critical limits. If the parameters in some pasteurization cycle are less than stated above, what would be acceptable from a HACCP point of view? Could the temperature stay at 80°C for 10 seconds for the process to be accepted? A table of temperature and time combinations, which are accepted, could be calculated. Then a set of temperature/time combinations would function as the critical limit. For simplicity, in this report one temperature/time combination will be settled as a critical limit.

Assume that a reduction of 7–8 log cycles is necessary. Then the organisms must be treated at 83°C for about 1.5 seconds. To get the critical (time) limit, this has to be adjusted to take the uneven temperature distribution into account. A reasonable safety margin could be to double the time to three seconds. The limits will be monitored using at least two continuous thermometers and a flow meter (since the pasteurization is a continuous process). The thermometers will be placed so that they cover the distance passed by the mixture during the three seconds. If ice cream mixture passes the pasteurization without the critical limits being fulfilled, it must be put through pasteurization once again. Also, the equipment after the pasteurization that got in contact with the mixture must be cleaned and disinfected before further use.

Aging

Rapid chilling of the ice cream mixture and keeping it at the correct temperature during the aging step is important, so micro-organisms are unable to grow. Even if the pasteurization works fine, organisms are present in the following steps. This is due to the heat resistant spores of *B. cereus*, and may also be due to inefficient cleaning and disinfection.

The temperature will be a way to prevent the microbial hazard. The critical limit will be set at 5°C (HKSAR Government, 2001). Though, the process is normally ran at 4°C. The limit will be monitored using a continuous thermometer. If the limit is exceeded the mixture must be discarded, or – if product quality is unaffected – re-routed back to pasteurization.

Toffee addition and packaging

Addition of toffee to the ice cream is a manual procedure. Also, the packing machine is filled with packaging manually. There is therefore a risk of contamination of the product in these steps. Hygiene in these steps is crucial for the product, since no elimination of pathogens is done later. Though, this is something for GHP to target.

Labelling concerning the allergenic ingredients in the product is a CCP. The critical limit is that the correct packaging is used. This has to be visually monitored by personnel as the packs are put into the packing machine. Good order must be kept among the packaging material so no mixing occurs. If the wrong kind is in a batch of packs, the whole batch of packs and all packs already used have to be visually controlled. If ice cream has been packed into the wrong kind of packs, it has to be discarded.

Hardening, storage and transportation

Freezing is not an efficient way to decrease numbers of bacteria. Even if some bacteria die, most survive. Though, freezing is the most successful technique for long-term preservation since the product is largely unchanged. The preservation principle is two-fold. At lowering the temperature the microbial activity decreases, since the rate of biochemical reactions is slower. Also, the freezing lowers the water activity. This is due to the increase in concentration of solutes in the unfrozen water.

Though, freezing does not decrease the microbial hazards. There is an example of *Salmonella* surviving in ice cream stored at -23°C for seven years (Adams and Moss, 2000). Bacterial survival rates vary, with the gram-positives being more freeze resistant than gram-negatives and bacterial spores being unaffected by freezing. Although survival cannot be prevented, growth of micro-organisms is stopped at temperatures below -10°C (Adams and Moss, 2000).

The hardening step in the toffee ice cream production is not critical for microbial hazards. The ice cream is already cold enough for halting microbial growth sufficiently, and whether the hardening takes one hour or one day is not crucial for microbiological quality. The step will therefore not be part of the HACCP plan. It is only for other quality reasons that the parameters in the hardening step are important. The same applies on the storage and transportation steps, which should have a temperature of -18°C. Product quality will be affected before micro-organisms are of concern.

Verification and documentation

A number of routines for evaluating and keeping record, of that the work is carried on according to the HACCP plan, has to be implemented.

Verification includes a validation of the HACCP plan before it is used and once a year for it to still be accurate. It must be checked so that it has a correct flow chart, all relevant hazards have been found, preventative measures have been found for each hazard, the critical limits are adequate, monitoring procedures and equipment work as they should, the line operators and supervisors are trained in HACCP, and responsibility for monitoring procedures and corrective actions has been assigned (Plym Forshell, 2006).

When the HACCP system is in place, verification procedures will ensure whether it is working or not. Each day observations and measurement data is reviewed. Every month there is a need for verification procedures such as reviewing deviations from critical limits, reviewing corrective actions, reviewing GHP, reviewing calibration and maintenance records, inspection of the process line, and random sampling for analysis of bacteria and mycotoxins (in ingredients, along the process line and in the finished product). A yearly review of suppliers' HACCP systems should be performed, as well as a review of the employees' training.

All records of delivery control, temperature data and packaging checks must be kept properly. The whole work regarding the HACCP plan – including background data, verification, and information on who is res-

ponsible for what – has to be documented as evidence for the system to work properly.

Summary

Here is a hazard plan summary table, as an overview of the HACCP system.

CCP	Hazards	Critical limits	Monitoring	Corrective actions	Records	Verification
Milk, cream and almond	Aflatoxin	No toxin	Supplier guarantee	Return delivery, change supplier	Delivery checks	Review of supplier, review records
Pasteurization	*Bacillus cereus*, *Listeria monocytogenes* and *Salmonella*	83°C for three seconds	Thermometer and flow meter	Repasteurization	Temperature, time (flow)	Review records
Aging	Recontamination	5°C	Thermometer	Discarding or repasteurization	Temperature	Review records
Labelling	Allergens	Correct pack	Visual control	Discarding	Packaging checks	Review records

The development of the HACCP plan is a continuous work. New hazards may be addressed, and changes in production lead to changes in the plan. With a good HACCP work there will be a low risk for hazard problems.

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