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Implementation of hazard analysis critical control point to Feta and Manouri cheese production lines

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Abstract

Nowadays Hazard Analysis of Critical Control Points (HACCP) has become a prerequisite for transactions involving food products. In view of the great variety of the latter a thorough HACCP analysis is required which should however be adapted to the specific needs and peculiarities of each product. Feta cheese and Manouri are two traditional Greek dairy products which have crossed the borders of other EU state members. Therefore, a thorough HACCP analysis of these two products has become an important issue for public health both at the national (Greek) and international (EU, USA, Australia, etc) level. This paper focuses on the flow diagrams based on the production lines of a dairy company in Northern Greece (Basdras, Katerini), and presents an analysis of the hazards and of the critical control points (CCP). © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: HACCP; Feta cheese; Manouri; Hazard

1. Introduction

The concept of Hazard Analysis of Critical Control Points (HACCP) is a preventive, structured, systematic and documented approach to ensure food safety (Buchanan, 1990, Motarjemi, Kaferstein, Moy, Miyagawa & Miyagishima, 1996). It is generally recognized that the production of cheeses with desirable organoleptic characteristics and safe for consumption can be assured only when the following factors are continuously controlled and tested:

- The microbiological quality of the raw milk.
- Pasteurization of the raw milk prior to cheese production.
- Prevention of recontamination after pasteurization of the milk and predominance of the desirable microbial flora during storage (Zottola & Smith, 1993).

HACCP is a scientifically based system which assures the control of these factors. It is a system aiming at the production of zero defective products which separates the acceptable from the non-acceptable or the essential from the non-essential. The conventional way of ensuring product safety in food processing by end product testing has several drawbacks. In contrast to the classical approach, HACCP establishes control systems that focus mainly on preventative measures rather than relying on end product testing (Dobson, 1995). It targets the identification of specific hazards (microbiological, chemical and physical) (Pierson & Corlett, 1992) and suggests the adoption of preventative measures for their control. The points in the flow diagram, where the hazards may occur, are critical to consumer safety, and are known as Critical Control Points (CCP's). The principles of HACCP, listed in Table 1, are primarily applied to microbiological hazards because the latter are the leading cause of many food-borne diseases (Potter & Hotchkiss, 1996). A flow diagram in a cheese-making plant, should include recording of the flow diagram steps starting from the incoming raw milk till the packaged cheese. The flow diagrams of cream and whey should be also included to the complete diagram.

HACCP was first used in the early 1970's to design regulations on low-acid and acidified canned foods, in order to protect the public health from botulism (Baird-Parker, 1992). Over the last ten years the HACCP concept has rapidly been developed and has found applications in various products such as: chilled and refrigerated foods (Bryan, 1990; Corlett, 1989; Potter & Hotchkiss, 1996), seafood (Spencer Garrett III & Hudak-Roos, 1991) and meat and poultry (Karr, Maretzki,

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Table 1
The seven principles of HACCP (Cullor, 1997)

1	Conduct a hazard analysis. Prepare a flow diagram and indentify the hazards
2	Identify the Critical Control Points (CCP's)
3	Establish critical limits
4	Establish monitoring system to ensure control of the CCP
5	Establish corrective actions to be taken if critical limits are exceeded
6	Document the HACCP plan
7	Verify the HACCP system

Knabel, 1994). Milk and milk products such as cheese are historically among the safest foods (Kosikowski & Mistry, 1997). However, the recent (80's) high number of separate outbreaks involving *Listeria monocytogenes*, *Salmonella* spp., *Escherichia coli* and *Streptococcus* spp. (Johnson, Nelson, & Johnson, 1990) made HACCP also essential for the dairy industry. During the latest years several applications of HACCP in milk and milk products, including cheese, have been reported (Dijkers, Huurnink, Pennings & Van den Berg, 1995; Jervis, 1992; Varnam & Sutherland, 1994; Lecocq, Gueguen, & Coiffier, 1996).

The aim of this study is to present the HACCP analysis on two Greek traditional cheeses; Feta cheese and Manouri which have recently gained ground in the markets of other state members of the European Union. Furthermore, comparison is attempted to the other studies referring to similar products by using the same or different technology.

2. Feta cheese

Feta is one of the most popular, internationally known, white brine cheese produced in Greece from ancient times (Anifantakis, 1991; Abou-Donia, 1991; Tamine & Kirkegaard, 1991). It is produced from sheep's milk or mixed sheep's and goat's milk in a ratio up to 7:3, respectively (Greek Codex of Foods and Drinks, 1998). The major characteristics of Feta cheese are the snow white colour, the pleasant slightly acid taste and the rich flavour. The texture is firm, smooth and creamy, and some irregular small mechanical openings are desirable (Anifantakis, 1991). The contents for moisture and fat-in-dry-matter are 51.5–57.1% and 46.2–53.3%, respectively (Table 2) (Abd El-Salam, Alichanidis & Zerfiridis, 1993; Vastardis & Anifantakis, 1992).

Feta differs from other brined cheeses in being dry-salted and free from food additives. Feta has a remarkable nutritional value since 100 g cheese are sufficient to cover the nutritional needs of a normal working man, that is 33% of high biological value proteins and vitamins A and B_2 and the 50% of needs in calcium (Zerfiridis, 1989). Feta is the principal cheese in Greece, where consumption can reach 12–15 kg per capita per annum (Zerfiridis, 1989).

Table 2
The composition of feta cheese (Abd El-Salam et al., 1993)

Moisture	54.3 ± 2.9 %
Fat-in-dry-matter	49.8 ± 3.6 %
Total protein	17.6 ± 1.2 %
Lactose	0.5 ± 0.3 %
Ash	4.1 ± 0.5 %
Salt-in-moisture	4.4 ± 0.8 %
Acidity (as lactic acid)	1.9 ± 0.7 %

3. Feta's flow diagram

After milking, the raw milk is chilled to below 4°C and kept at this temperature during its transportation to the dairy factory. After reception, milk is filtered and stored in large silo tanks and is sampled for analyses. The milk is standardized (casein/fat = 0.7–0.8), pasteurized (72°C × 15 s) and cooled down to 32°C. At this temperature, a starter culture is added and after 30 min rennet is also added and the milk is coagulated in 50–60 min. The coagulum is cut by using a 2 cm wire knife, it stays for 10 min and is transferred in thin layers into perforated moulds. The moulds are rectangular of dimensions $23 \times 23 \times 35$ cm^3. The curd is drained without pressing, until it is firm enough to remove the moulds. The cheese is cut into four blocks of $11 \times 11 \times 8$ cm^3. These blocks are dry salted on the surface. After 12 h the blocks are reversed and salted again. This is repeated until the salt content of cheese reaches 4%. After the cheese blocks have thus remained on the cheese tables for a few more days, the cheeses are packed into tin cans, containing 6–8% salt solution and kept at 14–16°C for about 15d until they attain pH 4.6 and moisture content 55%. The cheeses are then transferred to new containers where more brine is added and the containers are sealed and stored at 4°C. The cheeses can be consumed after two months have elapsed after manufacture (Fig. 1).

4. Analysis of Feta production CCPs

4.1. Raw milk

The milk should be obtained from healthy animals (goat and sheep) under hygienic conditions. The animals may often suffer by mastitis and in 95% of the cases the pathogens held responsible were: *Staphylococcus aureus*, *Staphylococcus epidermidis* and some *Micrococcus* strains (Tzanetaki, 1993). These microorganisms contaminate the nipple of udder because of their presence in the environment and milk equipment. The preventive measures are cleaning the udder before and after milking

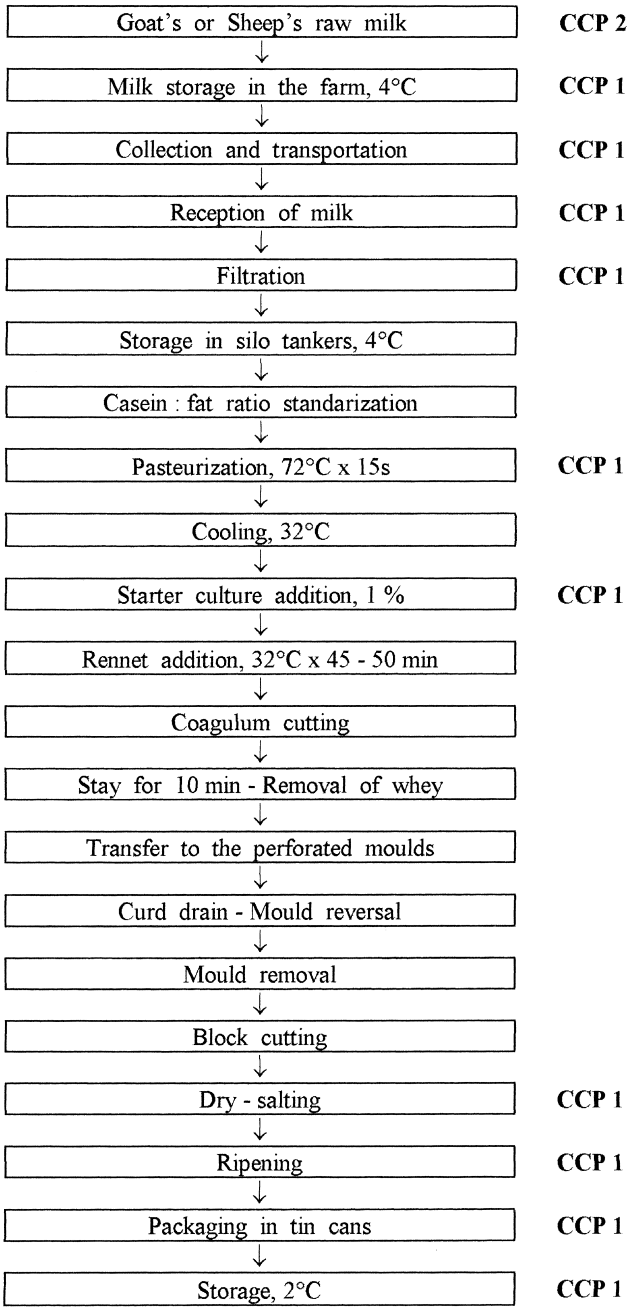

Fig. 1. Flow diagram of Feta cheese production where the CCP's have been indicated (*CCP 1*: ensures elimination of the hazard and *CCP 2*: the hazard can be controlled but not eliminated).

with appropriate antiseptics, controlling the microbial load of milking equipment and the equipment at the industry by thorough cleaning using a CIP-system (Clean In Place). The consequences of mastitis consist considerable decrease in milk production, composition changes and greater number of pathogens in milk. Some of them (*Mycobacterium*, *Brucella*) can move along the chain: animal→milk→cheese→human and cause food poisoning. Animals must be regularly examined by a veterinarian who should keep records for each one of them. An increase in somatic cells indicates an unhealthy animal. Then, antibiotics should be given to the animal and its milk is considered inappropriate for collection for at least 72 h (Gardner, 1997). The potential existence of antibiotic residues in raw milk prevents the efficacy of starter culture. The animal feeding must be also controlled regarding its content in various metals or other elements (Pb, As, Se, Hg, F, Mb and Cu), chemical organic substances (aflatoxins, chloride products) and presence of toxic plants (*Phalaris minor*, *Melilotus alba*, *Trifolium repens*, *Conium maculatum*, etc.) (Efstathiou, 1996). It is suggested that the animal should not be always fed with the same food.

4.2. Collection of raw milk

Milk is a excellent medium for growth of microorganisms. Therefore, there is a high risk of a quick microbiological deterioration of quality between the milking stage and the stage of plant processing. The milk should be transported in milk tankers directly to the dairy factory thus avoiding any unnecessary delay. Prior to transportation, the driver should check the milk acidity using portable pH meters. During transportation the temperature of milk should not exceed 10°C (Directive 92/46 EEC, 1992). The latter can be easily and quickly controlled with Time Temperature Indicators (TTI). Milk tankers should be thoroughly cleaned and the cleaning efficiency should be regularly checked.

4.3. Reception of raw milk

This stage is a CCP1 because the reception test stands for an acceptance test. The long exposure of milk to high temperature during transportation may favour the growth of pathogens and the production of heat resistant toxins. Raw milk contains pathogen bacteria, such as *Salmonella*, *Mycobacterium bovis*, *Brucella*, *Campylobacter* and *Listeria monocytogenes* (Skovgaard, 1990). Moreover, raw milk may contain antibiotics and aflatoxins (e.g. aflatoxin M). Control of raw milk includes the determination of milk acidity, aerobic mesophilic count, freezing point, antibiotic and metabolite residues (Table 3).

4.4. Filtration of raw milk

The raw milk is filtered in order to ensure the removal of any extraneous material which represents a physical hazard.

4.5. Storage of raw milk

If the milk is to be kept beyond the day of production, it should be kept refrigerated at a temperature below 6°C (Directive 92/46 EEC). However, at this

Table 3
Control measures of raw milk

Control	Method	Limits
Milk acidity	pH meters	pH: 6.2–6.65
Aerobic mesophilic count	PCA: 30°C×48 h	500 000 cfu/g
Freezing point	cryoscopic	−0.525°C
Antibiotic	BR-test	nd
Bacterial toxins (e.g., *S. aureus*)	Elisa test	nd

temperature, growth of psychrotrophic microorganisms and consequent production of proteolytic and lypolytic enzymes are observed. Although, these microorganisms are completely inactivated by pasteurization, the enzymes are very heat resistant and will continue to cause flavour problems even after the heat treatment (Burton, 1986, Wolfschoon Pombo, 1984). At temperatures below 6°C, *Bacillus cereus* grows and forms spores, which are unaffected by pasteurization. *Bacillus cereus* is of great importance because it is capable of producing a food poisoning toxin (Van Heddeghem & Vlaemynck, 1992; Christiansson, 1992; Griffiths, 1992). To avoid the risk of further growth of potentially troublesome microorganisms in raw milk, milk should be kept at the lowest possible temperature (4°C) and treated within 72 h. In order to extend the storage time, a number of complementary procedures have been reported, such as thermization (65°C×15 s), carbon dioxide addition and thiocyanate/lactoperoxidase/hydrogen peroxide addition, that is lactoperoxidase system (LPS) initiation (Varnam & Sutherland, 1994). Mixing already stored raw milk with recently received raw milk could result in cross-contamination and should be avoided.

4.6. Pasteurization

In a HTST system (High Temperature Short Time), the typical temperature-time conditions are 72°C for 15 s. The flow of pasteuriser cannot exceed that at which the 15 s hold was measured. Pasteurization is followed by cooling at 32°C. A positive pressure is maintained so that if a leak occurs it is from pasteurised milk. Moreover, routine checks of plates for leaks are carried out. Flow divert on under-pasteurisation temperature and key thermometers are verified daily. Holding time takes into account divert valve response time. This heat treatment will destroy all the vegetative forms of bacteria, the psychrotrophic microorganisms, the yeasts and the moulds (Burton, 1986). The surviving microorganisms are *Micrococcus*, *Streptococcus*, *Lactobacillus*, *Bacillus* and *Microbacterium* which constitute indicators of hygienic condition of equipment (Tzanetaki, 1993). Pasteurization must focus on minimizing the probability that pathogenic microorganisms might survive the process so that the public health risk is considered negligible. The procedure of pasteurization, however, can neither destroy nor eliminate the presence of toxins, bacterial agglomerations and residues of chemical and physical substances, such as antibiotics and metals. Therefore, the existence of at least one critical control point before pasteurization is essential (e.g. reception of raw milk). The most appropriate routine method to ensure that milk has been correctly pasteurized and afterwards not cross-contaminated by raw milk, is Flurophos which is far more sensitive than the standard alkaline phosphatase test (Harding, 1991). During pasteurization, the deposition of residues of milk components (proteins and minerals), at the inner surface of the processing plant (fouling), lowers the efficiency of heat transfer (Visser, Jeurnink, Scarml, Fryer & Deplace, 1997). The insufficient heat treatment may favour the survival of pathogenic bacteria. Should fouling occur because of insufficient heat treatment the pasteuriser should divert. The plate heat exchanger should be cleaned at least once a day (0.5% NaOH, 65–70°C). Cross-contamination of milk after pasteurization stands probably for the greatest risk of a hygiene breakdown (Criado, Suarez & Ferreiros, 1994). The essential sources of heat treatment contamination are air, water, equipment, utensils, people, starter cultures, rennet and packaging (Teuber, 1992; Parmentier, 1997). The quality control laboratory does frequently the sampling from the sources which are regarded suspect and prone to contamination.

4.7. Starter culture

For Feta cheese the following starters of lactic acid bacteria are used: *Lactobacillus bulgaricus-Streptococcus thermophillus* (1:1) (Pappas & Zerfiridis, 1989), *Lactococcus lactis–Lactobacillus bulgaricus* (1:3) (Abd El-Salam et al., 1993) and *Lactococcus lactis–Lactobacillus casei* (1:1) (Zerfiridis, 1989). The percentage of added culture is approximately 1%. After the starter addition, the mixture remains for half an hour at 32°C to promote the starter growth (milk ripening) and rennet is added. The preventive measures of this stage consist of monitoring the temperature of milk and controlling the development of acidity (pH reaches 5.0–5.2 within 6–8 h). The continuous activity of starter should be ensured. Any change in activity may indicate either contamination with bacteriophages or a decreased activity of the starter due to excessive presence of antibiotics and/or disinfectants and considerable variations in the composition of milk (Cogan & Hill, 1993). The most significant problem arises from bacteriophage, normally present in cheesemaking environment and especially in the whey (Cogan, Peitersen & Sellars, 1991; Lodics & Steenson, 1993). In order to avoid them, phage inhibitory media (PIM) for starter growth have been developed (Cogan &

Hill, 1993). It is generally suggested that culture addition should be supervised by experienced personnel under strictly hygienic rules.

4.8. Dry-salting

To assure an even distribution of salt, every 12 h the cheese-blocks are turned upside down and salted again on the surface. This continues until the cheese content in salt varies within the range 3–4%. Within the first 24 h, salt in moisture must be 2.5% (moisture content 60%). Higher values are not required because pH has already reached 4.8–5.0 (Spahr & Url, 1994). The slime formation on the surface of Feta is essential for the development of the characteristic Feta flavour during ripening. The composition of microbial flora at the surface should be also checked (Lenoir, 1984). The salt is usually of the size of corn and must be obtained from reputable supplier. Salting and ripening temperature must be monitored and kept at 16°C. Following dry-salting, which takes 4 to 5 days, the cheese is placed into tins and covered with brine of about 8% salt content. The tins are covered and left for ripening.

4.9. Ripening

Ripening occurs within approximately 15 days at 16°C and RH = 85%. Higher values of RH may favour the growth of moulds which produce mycotoxins. The ripening room must be separate and checked for its hygienic conditions. By the end of ripening, the salt in moisture is 5–6 %, pH is not above 4.6 and moisture content varies around 55%.

4.10. Packaging

The tin cans are refilled with 8% salt solution (brine) and the blocks of cheese are completely submerged to avoid mould growth at the surface and the potential aflatoxin production (Zerfiridis, 1985). The removal of each block from the ripening room should take place according to the FIFO-method (First In First Out). Salt-in-moisture levels within the cheese must be lower than the corresponding concentration of salt in brine. The tin cans are sealed and the efficiency of sealing must be also checked. Cans must be obtained from reputable supplier, and must be kept at controlled RH to prevent rusting. Prior to use, they are washed with potable water and their hygienic condition is checked with microbial techniques. After packaging the tin cans are transferred to the storage room at 4–5°C.

4.11. Storage

Ripening is completed within 2 months. During storage, psychrotrophic bacteria contribute to the continuing ripening thus improving the organoleptic characteristics and killing the pathogens *Salmonella*, *Brucella*, *Staphylococcus aureus* and *coliforms*. These bacteria might contaminate the product after milk has been pasteurized. The pathogen *Mycobacterium* endures extreme pH conditions and high values of salt concentration. For that reason, pasteurization must ensure the killing of this bacterium (Hammer, Knappstein & Hahn, 1998). The tin cans must be placed at dry places where the temperature remains at 4°C and RH is kept low.

5. Manouri cheese

Manouri cheese is one of the most popular whey cheeses produced in Macedonia (Northern Greece). It is produced from the whey derived from full-cream goat's milk or from mixtures of sheep's and goat's milk during the production of hard cheeses (Anifantakis, 1991). Cream and/or milk may be also added. Manouri is a white soft cheese endowed with firm texture. It is in the shape of a cylinder and does not have any holes. It is considered the highest quality whey cheese. The moisture, the fat and the salt content are 48, 37 and 0.8%, respectively. Furthermore, it has a high nutritional value because of its content in high biological value proteins, higher than the biological value of caseins of which most cheeses consist. Since the whey cheeses are characterized by a great variety in their composition, special concern is required for maintaining the appropriate hygienic conditions in the production line in order to avoid the uncontrolled growth of microflora.

6. Analysis of Manouri production CCPs (Fig. 2)

All the ingredients used, such as whey, milk, cream and salt constitute potential hazards. Therefore they should be of controlled quality and purchased only from reputable suppliers. Acidification of whey is required to pH 5.8, before or during heating, when the pH value is high (pH > 6.0) in order to avoid the growth of *C. Botulinum*. The added acids are citric, lactic and acetic acid. The heating rate must be controlled in order to reach the final temperature of 88–90°C within 40–45 min (Kalantzopoulos, 1993; Veinoglou, Baltadjeva Kandarakis & Vlasseva, 1984). The heat treatment aims at the separation of proteins and fat as curd and at the destruction of the vegetative forms of bacteria. Cross-contamination of product after production leads to the growth of a high number of microorganisms (coliforms, yeasts and moulds), because of the high moisture content. If the hygienic conditions are not strictly adhered to after heat treatment, the addition of a starter culture (1%) is recommended, when the curd temperature is below 50°C. Recording of temperature during heat

treatment must be carried out by experienced personnel at temperature reporting charts. When the temperature increases the ingredients must be added at the 70–75°C (Greek Codex of Foods and Drinks, 1998). For the purpose of drainage, moulds and/or cloth bags are used. The cheeses are submerged in potassium sorbate solution (15%) for a few seconds to avoid the growth of moulds later during storage. The cheese, in its final form, has the shape of a cylinder (diameter; 10–12 cm and length; 20–30 cm). Manouri cheeses are vacuum packed in plastic bags and can be consumed right after production, without ripening. The high moisture and lactose content make the product very vulnerable to microorganisms. Therefore, it should be stored at cooling temperatures (<4°C) and consumed within 10–15 days. The shelf-life of the product made from ultrafiltrated whey can be extended even for up to 6 months, without any alteration of the desirable organoleptic characteristics (Veinoglou & Kandarakis, 1984). If the temperature exceeds 4°C there is a great risk of toxin growth producing moulds (Fig. 2).

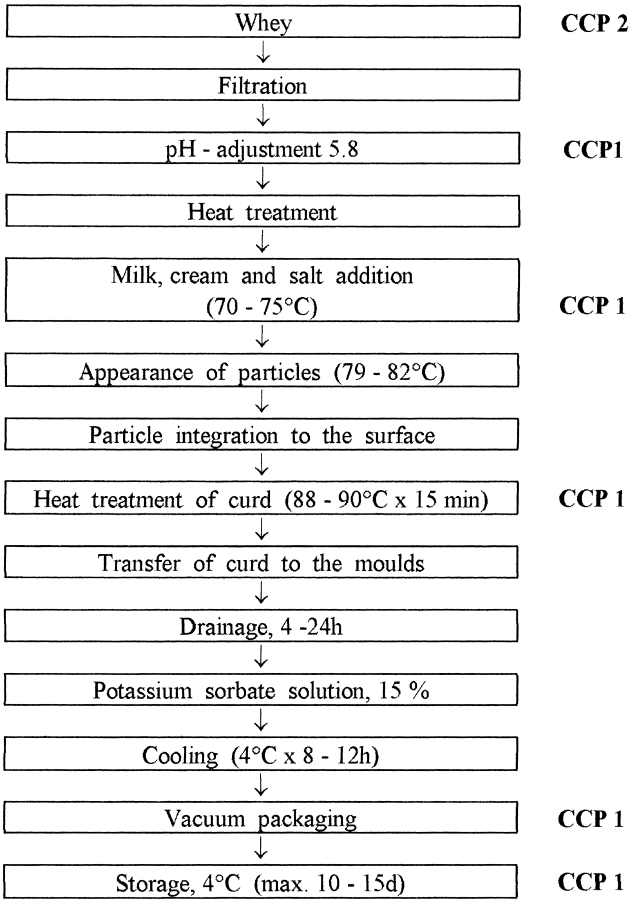

Fig. 2. Flow diagram of Manouri cheese production where the CCPs have been indicated (*CCP 1*: ensures elimination of the hazard and *CCP 2*: the hazard can be controlled but not eliminated).

7. Conclusions

Implementation of the HACCP system to the production of Feta and Manouri cheese proved to be a valuable tool for improving the safety and quality characteristics of these dairy products. In fact, the percentage of defective food items showed a substantial drop because the identification and efficient control of critical control points led to a stricter and, occasionally, automated on line control. Therefore, the overall performance of the cheese factory after the implementation of HACCP is judged satisfactory and further improvement is anticipated within the frame of a total quality system incorporating ISO 9002, HACCP and later on ISO 14001.

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