Quality Management Systems in Dairy Industry

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Abstract

Milk and milk products are the most important and necessary products in the food supply chain. Due to physical, chemical or microbiological hazards of possible contamination, many people in the world are exposed to these risks quite clearly. Therefore, sufficient quality and food safety practices are important for food security in the dairy industry. The most effective way to achieve food safety is to focus on prevention of possible hazards and to improve the process. The Hazard Analysis and Critical Control Points (HACCP) system has been indicated as one of the most effective ways to guarantee high quality and safe food. The main objective of Critical Control Points (CCP) is to identify problems before they occur, establishing control measures that are critical to maximizing food safety at each stage in the production process. In this study, the identification of critical control points in dairy sector, the identification of all potential hazards in raw milk, pasteurized milk, Ultra High Temperature (UHT) milk, cheese, ice-cream, butter and yoghurt production are reviewed. Description of critical control points, evaluation and orientation applied to prevent and control the critical points were presented.

Keywords
Dairy industry, HACCP, control points

1. Introduction

Milk can show large quality differences, which milk processors, must take into account. Two types of criteria are used for paying by quality physio-chemical and bacteriological. Physio-chemical criteria usually relate to the fat and protein content, the basic rate of which per kilo of milk varies from one to another. Testing for better bacteriological quality could result in finding specific bacteria such as *Coliforms*, *Staphylococcus*, *Listeria* and *Butyric* spores. Similarly, the presence of antibiotics and the milk temperature during collecting can be used as quality criteria and for price reduction. In addition, the presence of chemical residues could alter the process of elaboration of derived fresh milk products. (Karakok 2007; Vilar 2011).

Milk quality is all about prevention on each step of production. Quality control systems aimed the prevention of defects, rather than their detection. Quality control occurs at every step in the production, as a raw material on farm condition. Consumers, processors and regulatory agencies are increasingly interested in the safety and wholesomeness of milk resulting in increased emphasis on the farm management to insure the production of milk quality (Noordhuizen and Metz 2005).

The consumer demands safe and wholesome dairy products that can be purchased without any doubt. For raw milk the term quality is extremely comprehensive. There is a quality pyramid based for dairy products based on these kinds of perimeters. In summary, firstly the basic foundation of this pyramid is about the safety of these products, the second is the nutritional value and thirdly there must be the service to satisfy consumers for the long term. Some of the most important quality aspects are quality of content and physical-chemical condition, hygiene quality (bacteriological and cytological traits, absence of pathogens and other contaminants), sensorial quality, nutritional quality and technological quality (processing ability) (Karakok 2007).

2. Quality Management Systems in Dairy Industry

The HACCP system has become a synonym for sanitary security of food products. It is worldwide acknowledged as a systematic and preventive approach to control biological, chemical and physical dangers (hazards), by means of anticipation and prevention towards inspections and analyzes on finite products HACCP is a method which has to be applied by companies to secure the quality of food products, based on two main objectives:hazard analysis and determining the points, during the creation process, in which these dangers are controlled (Panfiloiu *et al*. 2010).

The HACCP concept is the best choice if a quality control programme should be designed for dairy farms. Particularly because it is highly farm-specific, easy to link up with operational management, relatively

low in cost, both product and process oriented, and not requiring much labour. ISO is very laborious and costly as well as far too non-specific to make it truly workable for a dairy farmer. In any case, a sound quality attitude of farmers and others involved is needed before one should even think about introducing HACCP or ISO (Noordhuizen and Metz 2005).

The application of HACCP has been incorporated into Codex guidance texts (Codex Alimentarius Commission). The determination of a CCP in the HACCP system can be facilitated by the application of a decision tree, which indicates a logic reasoning approach. Application of a decision tree should be flexible, given whether the operation is for production, slaughter, processing, storage, distribution or other efficient and accurate record keeping is essential to the application of a HACCP system. HACCP procedures should be documented. Documentation and record keeping should be appropriate to the nature and size of the operation (CAC RCP 1-1969).

Milk should not contain any contaminant at a level that jeopardizes the appropriate level of public health protection, when presented to the consumer. Contamination of milk from animal and environmental sources during primary production should be minimized. Water used in primary production operations should be suitable for its intended purpose and should not contribute to the introduction of hazards in milk (CAC/RCP 57-2004).

3. Evaluation of All Operations In the Process

Different and new methods are used in the production of milk and milk products, the application of heat treatment and the stages of storage and analysis with developing technology. Collected milk have to be kept in cold chain for protection of milk nutrient composition until it reaches the consumer. The number of microorganisms increase in milk without cold chain. Therefore, the pathogen microorganisms are get rid of, while maintaining the nutritional value of milk with applied heat treatment.

For the milk and milk products consumption in a healty way, production should be made under hygienic conditions and storage time-temperature needs to be controlled during the processing and packaging. If attention is not given, some dangers can be encountered in the specified stages in the flow diagram.

Hazard identification is helpful to identify potential microbiological, chemical and physical hazards that may occur during each step of processing. Microbiological hazards are pathogens or harmful bacteria introduced during production. Another microbiological hazard stems from improper personal hygiene. Chemical contaminants include the plant toxins and chemicals added during food processing. For example, the excess detergent left on the just cleaned equipment. A physical contamination is foreign material that could come from incorrect personal handling or bad environmental conditions (Zhao 2003). (BH: Biological hazards, PH: Physical hazards, CH: Chemical hazards).

Pasteurized milk is the largest selling milk in most industrialized countries because the consumption of raw milk carries the risk of infection by milk-borne pathogens, especially *Salmonella* and *Campylobacter* (Sandrou and Arvanitoyannis, 2000). The objective of milk pasteurization is to ensure the safety of fluid milk by killing pathogens known to occur in milk and to prolong shelf life by destroying undesirable enzymes as well as reducing the number of viable spoilage microorganisms. The target of pasteurization is to achieve 99.999% (5-log) reduction in viable microorganisms. Pasteurization is generally achieved with high-temperature/short-time equipment, which uses continuous heat processing combined with separation, standardization, and homogenization. The temperature-time combinations recommended for pasteurization have been selected to optimize microbial kill while minimizing the impact on the nutritional quality of milk **(**Meunier-Goddik and Sandra 2011).

UHT milk, in contrast to pasteurized milk, has extended shelf life at ambient temperatures, since the applied thermal process is capable of inactivating vegetative microorganisms and spores. Although UHT eliminates almost all psychrotrophic organisms, the latter frequently produce lipases and proteases, which manage to survive because of their thermo-resistance (Sandrou and Arvanitoyannis, 2000). UHT treatment of milk is a continuous process aimed at producing a ‘commercially sterile’ product, that is, a product in which bacteria will not grow under the normal conditions of storage when packaged aseptically. The basic principle of the sterilization process is the microbiological population in the processed milk, it also significantly affects the physical and chemical stability, flavor, color and nutritional value of the product (Deeth and Data 2011; Rosenberg 2002).

The quality of yoghurt depends on the type of raw material used, on the manufacturing procedure employed and on the proper functioning of the process equipment and process line. The physical and chemical properties of yoghurt change during microbial fermentation with *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. Other processing steps during yoghurt manufacture, including homogenization, heat treatment, mechanical handling, cooling, etc. have physico-chemical and biochemical effects. Processing is quality-controlled: milk is aseptically inoculated with starter culture; temperature is precisely monitored; and the yoghurt cooled quickly when the desired acidity is reached (Sandrou and Arvanitoyannis 2000).

Cheese making is the process of removing water, lactose and some minerals from milk to produce a concentrate of milk fat and protein. The essential ingredients for cheese are milk, rennet, starter cultures and salt. The semi-firm gel is formed by adding rennet that causes the milk proteins to aggregate at a certain pH; then, it is cut into small curds. Then, the whey (mostly water and lactose) begins to separate from the curds. Acid production by bacterial cultures is essential to aid in the expulsion of whey from the curd and largely determines the final cheese moisture, flavor and texture (Zhao 2003).

Ice cream and other whipped frozen dairy desserts are foams made up of air cells surrounded by a partially frozen emulsion. Ice cream consists mainly of water, fat, and milk solids–non-fat, in combination with sugars, emulsifiers-stabilizers, colorings, flavorings, and fruits or nuts. The purpose of auxiliary materials is to increase the satisfaction value of the products. Ice cream is a product obtained from controlled raw materials, processed through pasteurization, homogenization, maturation, cooling, freezing, through keeping the air in composition, with or without glazer, and sell in different casseroles or waffle. The analysis and evaluation concluded that pasteurization is the most appropriate stage high potential risk in getting ice cream**.** Rapid cooling at temperatures below 5°C should follow pasteurization, otherwise the viscosity of mix can increase considerably and melting of the ice cream will not be uniform. To ensure adequate freezing of the mix, the suitable type of freezer should be selected and its proper and safe operation should be maintained. Ice cream should be transferred to the ‘‘hardening room’’ immediately after freezing where the appropriate combination of temperature/time should be applied. Rapid hardening of ice cream is important for two reasons; first to prevent melting and formation of large ice crystals during refreezing and second to improve the sensory properties (e.g., texture and palatability) of the ice cream (Sandrou and Arvanitoyannis 2000; Panfiloiu *et al.* 2010).

Butter is a dairy product that is produced physically from milk, cream, or yogurt and it should not include fat/oil other than milk fat. Components of the product are determined by food legislation of related countries. But in general the product should include 80-84% milk fat, 15.3-15.9% water, approximately 1% non-fat dry matter and 0.03-1.8% salt. Butter should be produced using cream or yoghurt and its fat content should be at least 82% according to related Standard (Altun et al. 2011). To produce a high quality butter, it is essential to ensure correct treatment of cream after separation since the temperature at which this process is carried out enhances microbiological growth. Heating of cream by direct steam injection in combination with vacuum deodorization should be avoided because it causes high fat losses in buttermilk and deterioration of butter flavor. Mixing of different quality creams should also be avoided since it can barely wipe out the defects of the used raw materials (Sandrou and Arvanitoyannis 2000).

4. Determination of Biological, Chemical and Physical Hazards

The dairy industry is highly susceptible for incidents affecting the public image of their products. It means that all efforts have to be directed toward the quality features of the product and the production process that have direct association with the consumer concern. As stated above, this refers first of all to food safety, public health, animal health and animal welfare, and next, to the more classic, technological quality measures like milk cell counts, bacteria counts, antibiotic residues, and freeze point decrease (Noordhuizen and Metz 2005).

Most of the potential hazards identified are microbiological. Therefore, temperature treatments (e.g. pasteurization, ultra high temperature, scalding temperatures) or temperature control (cooling, freezing) are considered critical for rendering the end–product microbiologically safe. It was well understood that pasteurization, was proved to be successful as a CCP to control classical zoonoses e.g. Brucella, as well as newer foodborne pathogens. Filtration techniques are used in conjunction with pasteurization to further reduce bacterial counts in the end product e.g. pasteurized milk. Postpasteurization microbiological hazards e.g. cross contamination are generally controlled by applying strict rules of cleaning and disinfection as prerequisite programmes, while acidification, salting and brining ensure, especially in cheesemaking, the correct proliferation of microflora (Papademas and Bintsis 2010).

Chemical contaminants in milk comprise chemical hazards that may introduce during milk production, dairy processing or packaging. Veterinary drugs, heavy metals, radionuclides, mycotoxins and pesticides are chemical contaminants that can enter to animal feed and they have some residues in milk. The most contentious residues that ocur in milk are antimicrobial drugs. Total quality management and HACCP approach has an important role for preventing and controlling of chemical contaminants in milk and dairy products, especially antibiotics in raw milk shipped from the farm (Janed Khaniki 2007). Various hazards shown in Table 1 (Chandan et.al. 2008).

Table 1 .Various Biological, Chemical and Physical Hazards Associated with Dairy Products

Fluid Milk		**Cheese**	**Ice Cream**	**Dried Milk**	**Condensed Product**
Biological	**Chemical**	**Biological**	**Biological**	**Biological**	**Biological**
Salmonella *L.Monocytogenes* *S.aureus* *S.enteretoxin* *C.perfringens* *E.coli* *Yersinia* *Campylobacter* *B.cereus* *Shigella* *Brucella*	Antibiotics Pesticides Sulfonamides	*Salmonella* *L.Monocytogenes* *S.aureus* *S.enteretoxin* *E.coli* *Campylobacter* *Shigella* *Brucella* *C.botulinum*	*Salmonella* *Mold Spores* *L.monocytogenes* *E.coli* *S.aureus*	*Salmonella* *L.Monocytogenes* *S.aureus* *S.enteretoxin* *E.coli* *C.botulinum* *C.perfringens*	*Salmonella* *L.Monocytogenes* *S.aureus* *S.enteretoxin* *C.perfringens* *Yersinia* *Campylobacter* *B.cereus* *Shigella* *Brucella*
	Physical	**Chemical**	**Chemical**	**Chemical**	**Chemical**
	Insects Soil Glass Fragments Wood Slivers Metal fragments	Nitrates, nitrites Aflatoxin	Non-Food Chemical Vapors	Sulfonamides Antibiotics Pesticides	Antibiotics Pesticides

5. Application of HACCP at Dairy Industry

HACCP is a systematic method, preventive and sciencebased, which first priority is the safety of the products through risk identification and risk management in the production process. It has a proactive, rather than reactive approach, emphasizing food hazard prevention rather than the detection of harmful defects in finished food products. Its main objective is to identify problems before they occur, establishing control measures that are critical to maximizing food safety at each stage in the production process (Cannas and Noordhuizen 2008).

A critical control point (CCP) is “a step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level”. The important words in this definition are prevent (to keep from happening), eliminate (to get rid of), and reduce (to bring down). A CCP requires:

- establishing critical limit(s) for criterion separating acceptability from unacceptability,
- validating the critical limit(s),
- making the measurements that are needed to monitor criterion and timely detect deviations (Cerf and Donnat 2011).

In developing countries, various factors combine to compromise the hygienic quality of milk products: the organization of milk supply chains themselves, dysfunctioning of the regulatory systems and quality control structures. The problem is compounded by local climatic conditions, where both heat and, at times, humidity do not favor the preservation of the product in optimal conditions when the cold chain cannot be maintained (Faye and Loiseau 2000).

When raw milk is pumped to the transfer tanker, an automatic pump stopping above 6°C should be used and this temperature should not be exceeded during transportation. Transportation time should be as short as possible, avoiding any unnecessary delays. Moreover, milk tankers should be cleaned and disinfected at least daily, should be regularly inspected and maintained, and should not be used for transport of any other materials in order to prevent microbiological or chemical recontamination of milk. The tanker driver should not suffer

from infections, should conform to hygienic rules, and should not have access to stables in order to avoid contamination of milk with pathogens of human origin (Sandrou and Arvanitoyannis 2000).

Milk tankers should be cleaned and disinfected after discharging. Discharging areas should have adequate drainage and should be easily rinsed to avoid accumulation of water and raw milk residues. Milk should be conveyed from the tanker into the dairy building in closed hose or pipe systems. On receipt, raw milk should be subjected to the following controls by analytical laboratories performed according to Good Laboratory Practice for quality assessment :

- measurement of pH value and of titratable acidity;
- tests for sediment and antibiotic residues;
- measurement of temperature, which should not exceed 10°C;
- determination of its microbiological quality through validated rapid methods;
- determination of its composition;
- tests to ensure that milk has not been adulterated;
- somatic cell count (Sandrou and Arvanitoyannis 2000).

The management of the quality by risk analysis or identification of potential hazards linked to a product or a process (Hazard Analysis and Critical Control Points or HACCP-type approach), must be applied along the whole supply chain, from the cow to the consumer. For each identified potential risk, one identifies feasible corrective actions and control plans. A quantitative risk assessment determines the probability that the exposure to a particular risk can cause a disease for a given individual. It is necessary to take in account the predisposition or the sensibility of certain consumers to pathogenic agents. The risk factors linked to a consumer are age, immune system defenses, sex and stress levels. The measure of quantitative risks allows for the calculation of an "acceptable" risk level and for the establishment of quality norms or criteria adapted to the different situations (Faye and Loiseau 2000). Possible hazards, control and orientation of milk and milk products were shown in Table 2,3,4,5,6,7,8 (Papademas and Bintsis 2010 and Varnam and Sutherland 2001).

Table 2. Possible hazards, control and orientation of raw milk

Process Level	**Hazards**	**Control**	**Orientation**
Barns, places where the cows live	Breast and nipples infected with bacteria found in urine and feces	Beds must be designed by limiting the dirtiness at breast and nipples Beds are dry and clean	If required, the beds are changed and good management provides nutrient field keep clean on regular basis
Milking place	Breast and nipples infected with bacteria found in urine and feces Breast infected with at cleaning and drying Preliminary milking The infection of the hands of the person doing the milking	Cleaning the floor, wall and equipments after every milking Cleaning the breasts with allowed chemical materials and drying them Not contact with other milks and cows milk thrown out	Ensuring that the use of allowed cleaning materials after milking Ensuring that the use of allowed cleaning materials after milking Provision is made to control the waters on a regular basis Before milking, washing the hands or providing putting on rubber gloves
Milking equipments	Equipments not designed well especially, growth of bacteria as a result of not enough cleaning at rubber parts	Brush of appropriate places and after that control of shaking with clear water	Providing cleanliness using allowed chemical materials after every milking
Milk collecting tank	Growth of bacteria due to bad physical conditions, insufficient cooling and insufficient cleaning	Cleaning with brush using allowed chemical materials when the tanks are empty and shaking with clean water	Providing hygienic conditions

Table 3. Possible hazards, control and orientation of pasteurized milk

Process Level	Hazards	Control	Orientation
Raw milk taking	Raw milk infected with pathogen microorganisms	Bacteriological quality of milk	Not providing processed milk in contact with raw milk
Storage in cold	Growth of some bacteria in milk	Storage temperature at 5 ^{0}C or lower Storage milk more than specific time	Providing cleaning of store with appropriate hygienic rules after milk taken from store
Pasteurization (HTST- high temperature short time)	Not provide effective pasteurization	Doing phosphatase test Controlling working of equipments to be desired	The provision for keeping regular records of pasteurization Providing the prevention of infection using appropriate cleaning and disinfection methods
Cooling after pasteurization	Infection after pasteurization and growth of bacteria	Cooling fastly at -10 ^{0}C or belove this	Providing cleaning of tanks
Filling th bottles or cartons	Infection of bottles and cartons	Being the bottles washed well and cartons cleaned	Providing protection of bottles and cartons in hygienic conditions
Storage in cold and transport	Growth of bacteria in infected ones	Protection at refrigerator temperature	Providing protection in cold

Table 4. Possible hazards, control and orientation of UHT milk

Process Level	Hazards	Control	Orientation
Raw material	To be found and growth of microorganisms caused food borne diseases	Hygiene of milk collecting at farms Design and hygiene of collecting tanks and storage vessels Temperature and time of milk waited in containers	Recording of milk temperature Microbiological tests Providing hygienic of collecting tanks and storage containers
Cleaning and seperation	Microbial growth	Usage of seperator and design it hygienic	Providing hygienic equipments and appropriate processing conditions
Sterilization, homogenization and cooling	Failure of milk sterilization causes surviving of food toxic microorganisms Infection after process	Design of UHT sterilizator Place sterilizator correctly Specification of milk flow rate including pressure and temperature at sterilization Hygienic design of refrigerator and homogenizator Correct collecting and planned preservation	Providing suitability of temperature and flowing velocity Control of flowing valve Providing control of dirtiness on plaques and visual cleaning of equipments and corrosion Sterility and cleaning of homogenizator
Freezing and aseptic packaging	Not be sterile inside of aseptic packaging machine or packaging material or filling	Design of aseptic packaging machine The process of packaging according to the manufacturer requests	Cleaning of package surfaces (including closing chin) Convenience with specification of machine and packaging materials

	area inside packaging machine result milk infection	Activity of packaging machine during usage Fitting trained stuff Specification of packaging material Packages seen treatment manually after filling and closing	Recording of the performance of the machine Closing in good way Conditions found at packages after packager
Storage and distribution	Encountering of damage packages cause microbial infection	Packaging with cartons designed to protect from damage during transportation Control humidity to prevent becoming dense on packages Correctly stacking packages during storage and distribution Giving information to distribitors, shops and consumers about how the packages will be used	Packaging with cartons Transport at stores and shops during distribution

Table 5. Possible hazards, control and orientation of yoghurt production

Process Level	Hazards	Control	Orientation
Concentrated nonfat milk seen thermal process for 20 minutes at 85 ^{0}C	Finding of pathogenic microorganisms	Application of thermal processing	Providing of recording thermal process temperature and time
Addition of additive materials (stabilizators, sugar syrup)	To be infected with food additive materials	Food additive materials compliance with specification	Providing usage of additive material with suitable quality
Thermal process (12 minutes at 90 ^{0}C) Cooling inoculation at -40^{0}C		The killing of contaminated bacteria for growth of culture	Providing of recording thermal process temperature and time
Incubation Cooling		Control of pH	Providing to prevent growth of microorganisms infected with low pH
Packaging Cooling	Microbial infection		Providing of keeping packaging materials at hygienic conditions
Storage at refrigerator and distribution	Damaging of packages physically		Educating people with process techniques

Table 6. Possible hazards, control and orientation of cheese production

Process Level	Hazards	Control	Orientation
Milk standardization	Raw milk can be infected with pathogen microorganisms	Control of bacteriological quality of milk	Providing milk obtained with good quality
Pasteurization (HTST)	Failure of pasteurization causes live pathogens	The control of pasteurization effectiveness with phosphatase test	Providing records of pasteurization time and temperature
Addition of starter cultures	Slow acid formation can cause growth of other bacteria including pathogens	Control of acid formation	Providing starter obtained to minimize infection from trusted sources

Addition of enzyme (rennet) Discontinuation of clot Boiling (Temperature rises about 40 ^{0}C) Seperation of whey water Compression and salting Packaging Maturing	Microbial infection	Measuring pH for fermentation control Using appropriate cleaning programs	Providing hygiene of product and environment

Table 7. Possible hazards, control and orientation of ice-cream production

Process Level	Hazards	Control	Orientation
Mixing of additivites including skim milk powder, oil of milk and sugar	To be infected with additives	Compliance of additives with specifications	Providing usage of appropriate quality additives
Pasteurization	Failure of pasteurization causes live pathogens	The control of pasteurization effectiveness	Ensuring compliance with the official standards
Homogenizing	Infection after pasteurization	Adequacy of implemented cleaning program	Providing implementation of adequate clean-up programs
Cooling and storage of mixture in the refrigerator Freezing of icecream	Microbial infection	Temperature control	Providing appropriate temperature
Packaging Hardening and storage	Microbial infection	Cleaning of package equipments	Packaging materials should be stored in good hygienic conditions

Table 8. Possible hazards, control and orientation of butter production

Process Level	Hazards	Control	Orientation
Raw milk	Raw milk can infect with pathogenic microorganisms	Bacteriological quality of milk at cooling storage	Providing seperation of raw milk with heat processed product
Seperation and pasteurization of cream Cooling below 5 ^{0}C and maturing	Failure of pasteurization cause pathogen survival	Control of pasteurization effectivity with phosphatase test	Providing keep records of time and temperature
Brine addition for setting salt-water ratio	If emulsion not being correctly, existing bacteria can grow	Including small water droplets in emulsion	Providing the prevention of bacteria growth with emulsion control

6. Conclusions

The study designed an HACCP plan model, food safety management systems and the applicability of this systems for raw milk, pasteurized milk, UHT milk, yoghurt, cheese, butter and ice-cream to improve the safety and quality of products. This study proves that with only some adaptations and modifications, the HACCP systems can be developed and carried out in an individual way in dairy industry to get high quality products.

The use of food safety and quality assurance in farms and plants is very important to reduce chemical and microbiological hazards in milk and dairy products. A regulatory law implementation in milk and dairy industries and long term planning is required to achieve milk safety. In addition, there are other items such as training of personel or latest good manufacturing practices and monitoring.

Firstly, the milk and milk product (pasteurized milk, UHT milk, yoghurt, cheese, butter, ice-cream) processes were investigated. Then application of HACCP at dairy industry were performed to improve the safety and quality of its products. HACCP is a universal system that ensures the food safety for import and export of dairy products. As a result, description of the critical points in which hazards can intervene in the production processes of milk and milk products, evaluation and orientation applied to prevent and control the critical points were presented.

From the literature review, it was observed that HACCP is an improved system compared to the traditional sampling and testing of quality control. Not only because it is a prevention instead of a reaction which reduces the risk of processing and selling unsafe products, but also because it is a cost-effective program which is fairly useful in milk and milk products production. Operational pre-requisite programs and risk analysis need to be established for the effective applicability of HACCP that determine physical, chemical and microbiological hazards in dairy industry.

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