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Sources of Contamination in Dairy Supply Chains and Approaches to Quality Control

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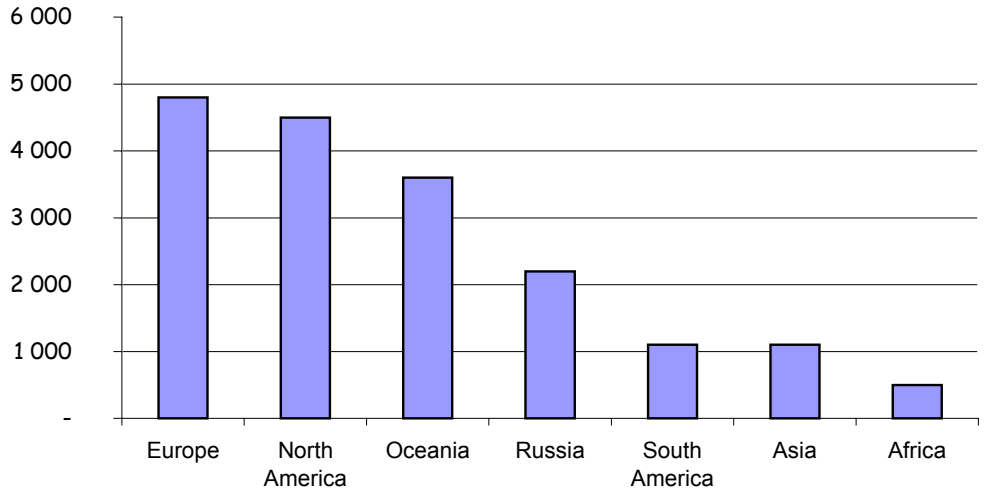
Abstract
Although consumption in developing countries still lies far below the levels in Europe and North America, the local markets for dairy products are on the rise, thanks to population growth and, in some regions, increases in per capita intake linked to economic expansion. Raising the hygienic quality of milk is critical for the local supply chains, which face greater challenges in this respect than those in temperate climates. Worldwide, there are two alternative models to ensuring dairy product safety: in the U.S.A., the focus is on regulatory control and sterilization, while in Europe the focus is on managing quality and safety along the chain, from the cow to the consumer. This latter approach would seem more appropriate in the developing country context, where regulatory systems are weak and where contamination problems occur all along the chain. Examples of the chain approach to hazard analysis are given for milk in Uganda and cheese in Brazil.

Introduction

Milk is a natural food with a clear nutritional value. Its production has been organized for over 10 000 years. Since the 19th century, dairy output has not ceased to increase thanks to progress in veterinary medicine, selection of improved breeds and development of improved breeding practices. At present, the mean annual milk production per cow is 7 700 l in USA and 5 500 l in France. However, high disparities can be observed across continents (Figure 1), and there are also considerable within-country variations: the most efficient dairy cows for example are producing 10 to 12 000 l per annum, and the world record lies at 24 000 l.

Figure 1. Mean annual milk production per cow per continent (kg)



The Changing Map of Dairy Consumption

The world population of dairy cows, estimated at 228 millions heads, produces 480 millions tons of milk. Other species are also involved in milk production: small ruminants (goats and sheep), buffaloes, camels, yaks, horses. Per capita milk consumption is higher in developed countries: 100 kg/person/year in the U.S.A., 70 kg in Europe, versus under 40 kg in developing countries. The causes of such disparities are numerous: climate, breeds, breeding practices, food habits, conflicts and political instability. However, an increase in both production and consumption has been observed over the past decade in developing countries, owing to changes in the consumption patterns in countries with high economic growth (for example, in Vietnam, milk consumption was 0.5 kg/person/year in 1990 and jumped to 5.5 kg by 2000) as well as the effects of population growth.

Among actions which can be undertaken to encourage the development of dairy supply chains, the improvement of the quality (and notably hygienic quality) of milk products is critical. For several years, CIRAD has been involved in projects working with developing country partners to encourage local dairy chains to meet increased local demand. Several ongoing projects aim to identify the risks associated with the production, the transport, the processing and the preservation of dairy products and to adapt technologies to local conditions. To support these projects, CIRAD has set up a cross-program co-ordination body entitled LAITROP (an abbreviation of the term “tropical milk”).

Milk Content and Composition

The components of milk and its physical and chemical properties provide a very favorable milieu for the multiplication of micro-organisms. Micro-organisms are naturally present in milk and their multiplication doesn’t start immediately after milking, thanks to milk’s natural bacteriostatic properties. This protection is efficient for several hours following milking. It is

necessary to take advantage of this period to cool the milk to check microbial growth. In milk coming from a healthy animal, when good hygienic practices have been respected, the total aerobic mesophile microbial flora (TAMF) could be between 10^3 and 10^5 germs per ml. When the TAMF surpasses 10^6 germs per ml, the milk quality is too low and it cannot be used. A milk with an initial TAMF below 10^4 will not reach the limit of 10^6 germs per ml for at least 4 days if the preservation temperature is at 4°C. This falls to 2 days with an initial TAMF of 10^5. With a temperature above 25°C, a good quality milk cannot be preserved more than one day. However, some differences can be observed according to the species. Camel milk, for example, is particularly rich in lysozymes and can be preserved at ambient temperature for 24 to 48 hours.

Cooling reduces the bacterial growth but cannot eliminate the micro-organisms already present in the milk. It also favors the predominance of psychrotrophic bacteria, which are proteolytic agents, leading to a degradation in the nutritive quality of the milk. Contamination by the natural micro-organisms of the milk is often compounded by contaminants from a range of origins. A non-exhaustive list is reported in the enclosed tables. In cooled milk, pathogenic bacteria can persist, as can deterioration bacteria, saprophytes bacteria, yeast, fungus and viruses. Some of these pathogens can be dangerous for humans and trigger non-specific digestive disorders (pathogenic strains of *staphylococcus sp.* for example) or specific diseases (e.g. main zoonosis as tuberculosis or brucellosis). The recommended methods of treatment and preservation processes, as well as the uses of the milk (milk for drinking, fermented milk, cheese, powder milk) depend on the type and number of micro-organisms present.

Managing Quality Along the Supply Chain

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. Studies done in Africa show that all the potential hazards linked to poor quality milk are present. This situation is also common in South America and in Asia.

Two alternative approaches are used in the world to ensure the safety of dairy products. In the U.S.A., control and sterilization are the predominant methods, whereas in Europe quality and safety are managed all along the supply chain. In light of the situation observed in tropical countries and the results obtained in Europe, it seems opportune to promote the latter approach to guarantee the dairy product safety in developing countries.

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.

As an example of the supply chain approach to milk safety and the identification of hazards from cow to consumer, the following two tables provide the results of the qualitative studies conducted by CIRAD scientists of dairy supply chains for 2 types of products: milk in Uganda (Table 1) and cheese in Brazil (Table 2).

Table 1. The Milk Supply Chain in Uganda

Steps	Hazards	Risk factors
Farm	• **Fecal Contamination** : *E. coli, Salmonella, Clostridium*	Transmission by the hands of the milkman Contamination by the animal at milking, by the tail and the splashes when the bucket is near the animals
	• **Contamination by environmental germs** : psychrotrophes flora (*Listeria, Pseudomonas*), Enterobacterias, yeast and fungus	Milk in open air at milking time
	• **Multiplication of bacteria on milking material**	Inefficient cleaning and disinfecting of material and/or poor drying
	• **Contamination by pathogen bacteria** : *Staphylococcus aureus, Steptococcus, Listeria, Mycobacterium tuberculosis, bovis, Brucella, E. coli*	Healthy carrier animals: *Mycobacterium, Brucella*, Animals with mastitis: *Staphylococcus, E coli*, Man : *Staphylococcus sp., Steptococcus sp.* Environment : *Listeria sp.*
	• **Contamination by chemical residues**	Non-respect of waiting time for veterinary medicine
	• **Lipolysis and raw milk turning rancid**	Frequent and brutal decanting
	• **Proteolysis : gelification of UHT milk, decreasing of cheese yield; appearance of sour components**	Collecting milk with mastitis
	• **Inhibition of the lactic fermentation : problems for milk processing**	Collecting milk from animals treated with antibiotics
Transport	• **Growing of microbial flora**	Carrying time too long, at high temperature
	• **Contamination by material**	Cleaning and inefficient disinfecting of material and/or bad drying
Collecting center	• **Cross-contamination**	Cleaning and inefficient disinfecting of materials Absence or bad quality control of the milk before mixing
	• **Human contamination**	Hand contacts with the milk at the time of sampling
	• **Contamination by environmental germs**	Use of contaminated water for cleaning the material
	• **Development of psychrotrophic flora : synthesis of proteolytic thermostable enzymes**	Temperature of cooling tanks not regulated and too lengthy storage
	• **Development of coliform flora**	Absence of cooling
	• **Lipolysis**	Manual filling of the tanks from the top
Dairy plant	• **Cross contamination**	Absence or bad quality control of the milk
	• **Recontamination by environmental germs**	Non hermetically sealed packing Poor hygiene at packaging
	• **Persistence of micro-organisms**	Absence of thermal treatment or insufficient treatment : no respect of time/temperature
Consumers	• **Food-borne disease : diarrheic syndrome, listeriosis, tuberculosis, brucellosis**	Consumption of contaminated raw milk
	• **Poor preservation of milk**	Poor quality (fragility of the components) High temperature and too lengthy preservation

Table 2. The Cheese Supply Chain in Brazil

Steps	Hazards	Risk Factors
Milk	• **Presence of pathogen micro-organisms :** *Salmonella, Staphylococcus aureus*, *E. coli,*	Poor health status of the herds Poor hygiene of collecting
	• **Presence of deterioration micro-organisms**	Absence of cooling Transport time too lengthy
	• **Cross-contamination**	Poor cleaning and disinfecting material Poor hygiene of housing and staff Absence of systematic control upon arrival
Cheese plant	• **Contamination by the staff**	Poor staff hygiene Absence of cloth and head-dress Absence of fresh water and/or good quality water Absence of toilets and washbasin Absence of "quality culture"
	• **Contamination by materials**	Absence or bad cleaning and disinfecting of materials
	• **Contamination by the environment : dust, insects**	Open housing with bad cover, close to pig farms, presence of flying insects
	• **Contamination by the process water**	Low availability of water, absence or bad decontamination of treatment, absence of control of the water's microbiological quality
	• **Persistence and multiplication of pathogen and deterioration germs**	Use of raw or badly heated milk Absence of pasteurization Use of highly contaminated milk
	• **Swelling cheese**	Process steps for making cheese adapted to the taste of the consumers: less salty, less dry, less acid; low level of refinement Low or insufficient lactic acidification: insufficient number of natural fermenting agents, badly adapted to making conditions, non controlled washing, not using selected fermenting agents Low enzymatic coagulation: bad quality of enzymatic preparations used at very high temperatures. High temperature and humidity in the workshops
	• **Development of contaminants in storage and transport**	Absence of cool storage Hermetic packing Absence or bad cooling in storage, transport and distribution
Consumers	• **Food-borne disease: diarrheic syndrome**	Absence or insufficient control quality of the products