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Microbiological quality of cows' milk taken at different intervals from the udder to the selling point in Bamako (Mali)

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Abstract

The microbiological quality of raw cows' milk, taken at different intervals from the udder to the selling point in Bamako was studied. Prior to taking the milk samples, each container and all the related material used were flushed with sterile water and bacteriological determination were made. A strong increase in the total count (TC) of bacteria was observed during transport from the farm to the market (10^7 colony forming unit per ml (CFU ml^{-1})). The main indicators considered were TC, Enterobacteriaceae and *Staphylococcus aureus*. The milk containers of the farmer and the milk vendor played a major role in the increase in the milk flora that occurred during transport from the farm to the selling points.

Keywords: Milk quality; Contamination; Bamako

1. Introduction

In Mali, agriculture and livestock contribute to about 23% of total export earnings and 40% of the gross domestic product (GDP) (Comptes économiques du Mali, 1999).

Similar to other African countries (Owango et al., 1998), Mali has undergone several forms of liberalisation in livestock services and marketing of animal products. The local dairy sector did not really benefit from these reforms which were expected to result in a strong market for local dairy products.

Today, with its livestock population estimated at 6.9 million cattle, 15.4 million small ruminants and 236,000 camels, Mali can not meet its domestic demand for dairy products. Local production is still very low and the average consumption is estimated to be 12 kg/person/year of which 60% is met by imported milk (Debrah, Sissoko, & Soumaré, 1995).

Spoilage and contamination may occur in the milk chain as a result of poor hygiene, long periods of transportation and lack of appropriate storage facilities. Deficient hygiene has often been considered to be one of the major causes of spoilage of products, resulting in a loss of income, both for farmer and smallholder dairies. The objective of this study was to identify the relevant sources of contamination and critical points in the chain of locally produced fresh bovine milk.

2. Materials and methods

2.1. Assessment of the production chain of local fresh milk

Local milk production and the marketing chain (from the udder to the selling points) were studied. The herd structure, milk yield and milking frequency were assessed.

Of the 18 selling points identified in Bamako, three were randomly selected representing the three main milk production systems in the country.

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The traditional system, in suburban areas using local breed (N'dama, Zebu) where traditional methods are practised and where there are no food supplements and milk production is low. The "modern" production system practised on farms owned by civil servants and business traders. It consists of mixed farming (livestock, orchard, cereals) with a high input of food supplements (cotton seed and salt). Milk production is relatively high. Cross breed of local breeds with Montbeliard, Holstein, and "Rouge des steppes" are used. The semimodern system, found mainly on private farms, which raise local and cross breeds of cattle on natural pasture. The level of feed supplement is low and so is milk production. The same methods of milking are used in all systems. The herder (male) lets the calf suckle for 1–2 min, after that the cows are hand milked into the calabash. Milk from the calabash is poured through a sieve or piece of cloth into a container (bucket or can). The milk container is open throughout the milking process. The vendor then collects the milk and again pours it through a sieve or piece of cloth into another container. The milk is then transported to town on a bicycle.

The hygiene in the chain was assessed by observation and evaluated according to the recommendations of the International Dairy Federation (IDF, 1990). Milk from traditional and semimodern systems was not heat-treated and was sold by men at the side of the road, whereas milk from modern systems was heated (90 °C) at home before sold by a woman on the family compound in town.

2.2. Sample collection

Sampling took place in the hot season (May–July 2001). This period includes the end of the dry season and the beginning of the rainy season. Samples were collected in the early morning.

The material of the containers in the chain varied from wooden calabash to plastic and steel. Transport containers have a very small opening, which is not easy to clean. Their volume varies from 0.25 to 30 l.

Well water (100 ml) from the household jar was collected in a sterile tube. The same water was used by the vendor to rinse his container. Prior to milking, the contamination of the surface of the material and the containers was determined by flushing all containers with 100 ml of sterile water. The calabash was rinsed first, followed by the funnel, sieve, bucket or can. Finally, the vendor's containers, including the funnel and sieve, were flushed. Each sample was poured into a sterile screw-topped bottle.

Three milking cows were randomly selected on each farm and the milk of each cow (from the four teats) was collected directly in sterile screw capped-flasks one for each sample. Subclinical mastitis was diagnosed by the California Mastitis Test (Pacovis^{AG} Belp-Suisse solution) for each cow. During milking, two different Petri-dishes, one containing nutrient agar (NA) (Merck, 1.045450) and the other Sabouraud (Merck, 1.05438) were exposed to the herd for 5 min to assess environmental contamination by total counts (TCs) and yeast/mould counts.

After milking the whole flock, the pooled milk was collected simultaneously from the farmer's and from the vendor's containers. Another sample was collected at the selling site. The distance and the time taken between the farm and the selling point as well as the ambient temperature were measured. The vendor in the traditional system collected milk from two additional herds. At the selling point in the modern system unheated and heated milk were simultaneously sampled. All samples were kept in ice cooled box and transported to the laboratory for analyses. Samples reached the laboratory at a temperature range between 8 and 10 °C.

At each visit, farm management and general hygiene were evaluated with emphasis on milking procedures, cleaning of containers and material and the environment (dust) using standardised protocols (FAO & WHO, 1997). Each chain was evaluated three times a week, according to the sampling scheme shown in Table 1.

2.3. Milk analysis

The specific gravity test, the whiteside test, the alcohol test and the methylene blue reduction test were performed according to the IDF (1990).

Milk, rinsed water and water samples were serially diluted, TC, and Enterobacteriaceae, *Staphylococcus aureus* yeast/mould were enumerated to assess the milk, containers, and water quality. Standard procedures according to the guidelines of the Swiss manual for food analisys (2000) were applied to bacteriological examinations.

2.4. Statistical analysis

Data obtained from the farm and the market were analysed by means of general descriptive statistics (geometric means). The TC of water (100 ml) rinsed from utensils was divided by the volume of the corresponding container to determine contamination (colony forming unit per ml, CFU ml^{-1}). The volume of the container varied, but the bacteria counts were not corrected for this variation. Ten CFU ml^{-1} was used for the undiluted milk samples with counts equal to zero. The TC and Enterobacteriaceae count less than 10 CFU ml^{-1} were used after confirmation by Gram staining (Merck, 1.11885).

Log transformed from TC and Enterobacteriaceae counts was regressed against critical contamination points (cow's udder, farm, vendor at farm vendor at market) and the containers used (SAS, proc glm).

Table 1
Schemes of sampling water, containers, milk and environment

Milk chain	Systems	Origin of samples	Sequence (2001)			Total
			May	June	July	
Producers	Traditional	Water	1	1	1	3
		Container	1	1	1	3
		Individual cow's milk	3	3	3	9
		Pooled milk from the farmer's containers	1	1	1	3
		Environment	2	2	2	6
	Semimodern	Water	1	1	1	3
		Container	1	1	1	3
		Individual cow's milk	3	3	3	9
		Pooled milk from the farmer's containers	1	1	1	3
		Environment	2	2	2	6
	Modern	Water	1	1	1	3
		Container	1	1	1	3
		Individual cow's milk	3	3	3	9
		Pooled milk from the farmer's containers	1	1	1	3
		Environment	2	2	2	6
Vendors	Traditional	Pooled milk from the vendor's containers at the farm	1	1	1	3
		Pooled milk from the vendor's containers at the market	1	1	1	3
	Semimodern	Pooled milk from the vendor's containers at the farm	1	1	1	3
		Pooled milk from the vendor's containers at the market	1	1	1	3
	Modern	Pooled milk from the vendor's containers at the farm	1	1	1	3
		Pooled milk from the vendor's container at the market	2	2	2	6
Milk markets		Boulkassoumbougou	10	10	10	30
		"Gare ferrovière"	10	10	10	30
		"Faladié-Monument"	10	10	10	30

Comparisons of the control points were made using linear contrasts.

3. Results

3.1. Production and handling of milk

On average, lactating cows were nine per farm. Milk production and other parameters are given in Table 2.

The farmers and vendors used mainly (67%) plastic containers (polystyrene cans (20, 10, or 5 l), replacing the local calabash in urban areas. The transport of small quantities is subject to transferring the milk to several containers from the producer up to the market. The milk passes through at least fore to five containers, two funnels and two sieves before reaching the container, which is sold to the consumer.

The containers are difficult to clean thoroughly. Soap is rarely used and washing of hands and udders was not common practice.

The temperature variation between the farm and the selling point was +4.3 °C (farm: 27.1 °C, selling point: 31.4 °C). The temperature of the milk decreased from the udder (37.0 °C) to the selling points (33.4 °C).

Table 2
Farm, milking and transport parameters

Parameters	Average	Minimum	Maximum
Cattle size/farm (*n*)	27	16	35
Distance farm to market (km)	11	5	15
Milk yield/day/farm (l)	15	–	–
Milking time (min)	30–45	–	–
Time between milking and first selling point (h)			
Traditional system	2.30	–	–
Semimodern system	1.30	–	–
Modern system	3.00	–	–

3.2. The contaminants in the milk chain

Handling small quantities of milk is subject to a high rate of contamination with a small ratio of milk volume to container volume (0.25). One third (31.1%) of the milk at the market was positive to the alcohol test and 8.6% was adulterated.

Subclinical mastitis was found in 44% (4/9) of the cows (at least one positive quarter per cow) and 22% (2/9) in pooled milk at the market.

The TC, Enterobacteriaceae, *S. aureus* and yeast/mould counts of different sources of contamination (environment, water, milk from the udder and containers) are presented in Fig. 1. The highest counts were found in the vendor's, followed by farmer's containers ($P < 0.05$). Subsequently, the milk flora in the chain were due to all the sources of contamination, with an important input of flora from farm containers (both calabash and milk can) ($P < 0.0001$) followed by the vendor's containers ($P < 0.02$). There was not a significant variation in the bacteria counts among the three sequences in the different milk chains.

The Pearson correlation coefficient between Enterobacteriaceae counts and TC was 61.3%. The TC was then used to test the variation in the critical point, where different contamination sources contributed to the microflora in the milk (Fig. 2). Heated milk data are not included in Fig. 2.

The linear contrasts of TC showed significant differences between the control points. The significance is described as follows: $P < 0.0001$ between the milk of individual cows (MIC) and pooled milk from the farmer's containers (PMF); $P < 0.0257$ between PMF and pooled milk from the vendor's containers on the farm (PMV-F) and $P < 0.0001$ between MIC and pooled milk from the vendor's containers at the market (PMV-M).

The average methylene blue reduction time decreased from the farm to the market with 5 h for MIC, 4.17 h for PMF, 3.13 h for PMV-F and 2.1 hrs for PMV-M. The

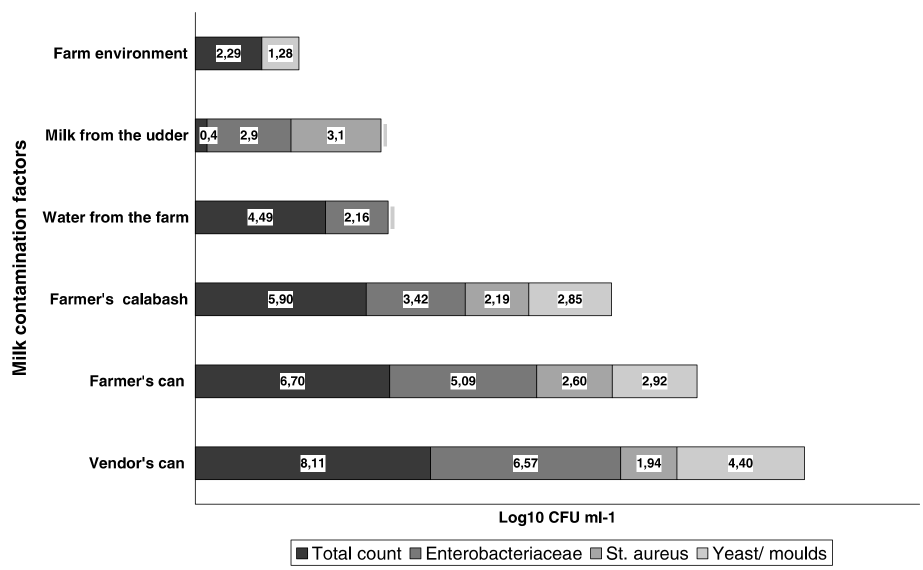

Fig. 1. Log 10 of microflora (TC, Enterobacteriaceae, *S. aureus* and yeast/moulds on milk contamination factors).

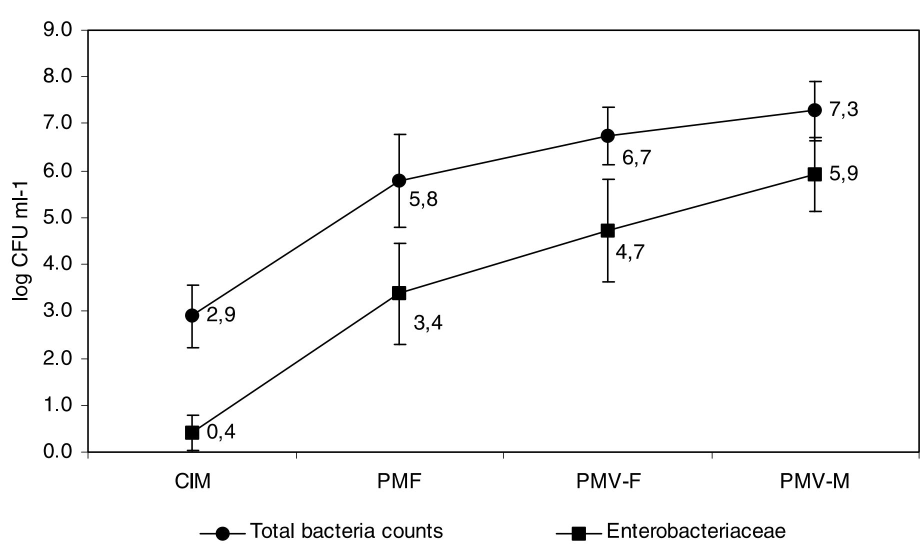

Fig. 2. Evolution of milk contamination (log 10 TC and Enterobacteriaceae in three milk chains).

reduction time is significantly correlated ($P < 0.001$) with the critical control point of milk in the chain. This denotes the exponential increase in contamination from the cow's udder to the selling point (Fig. 2).

The hygiene in the traditional system was better than in semimodern and modern system. The modern system showed a higher rate of contamination ($P < 0.05$) due to handling and management practices and the unhygienic environment. However in that system, milk was boiled (90 °C) before selling, but milk was recontaminated ($TC = 1.1 \times 10^3$ CFU ml^{-1}) due to the poor hygiene of the containers which were used during cooling and marketing. The final milk bacteriological count at the three selling points was 10^7 CFU ml^{-1} for TC and 10^5 CFU ml^{-1} for Enterobacteriaceae.

4. Discussion

The milk collected by the vendor from the farm was already highly contaminated by the containers used. Microbial counts in raw milk before it leaves the farm, depend not only on contamination during milking and storage but also on the temperature at which milk is stored and on the time that elapses between milk production and collection (Soler, Ponsell, De Paz, & Nunez, 1995).

The health of the dairy herd, milking and pre-storage conditions are also basic determinants of quality (Aumaitre, 1999). Another source of contamination by microorganisms is unclean teats. However in the present study the bacteriological counts in milk due to unclean udders is low but intense manipulation of small quantities of milk using several containers increased the count of microflora in milk. The use of unclean milking and transport equipment contributed also to the poor hygienic quality of the milk sold. These observations are in line with findings in Kenya (Godefay & Molla, 2000). The initial microbiological quality of the milk varies considerably and depends for the most part on the cleanliness of containers. The wooden calabash and most of the plastic containers are porous and make cleaning difficult. Calabashes are reported to harbour *Lactococcus*, *Leuconostoc*, *Lactobacillus*, *Enterococcus* and *Streptococus* (Beukes, Bester, & Mostert, 2001). According to most of the farmers, in this trial calabashes were not washed so as to preserve the existing starter cultures. The development of a local, acceptable, affordable and cost-effective starter culture for the production of fermented milk could make this practice redundant and would probably help to reduce contamination.

Gran, Mutukumira, Wetlesen, & Narvhus (2002) showed that sanitation and water are extremely important if contamination of food is to be avoided. Wells are the main sources of water used by 66% of the household in urban and suburban Bamako. This water is usually contaminated because the wells are usually located near cess pools (Breukers-Sissoko, 1997).

While the demand for dairy products increases with population growth (4.5% per year), there is growing public concern about the level of contamination reported in this study. Up to 70% of the cases of diarrhoea in infants may be milk related in Sahelian countries, where milk is used as basic food for children at early ages (WHO, 2000).

5. Conclusion

The number of containers used in the milk chain was the main source of contamination. High ambient temperatures coupled with general lack of refrigeration and poor standard of hygiene means that the milk, which often contains a large number of bacteria, acidifies on its way to the market. Challenges for future are: a broad microbiological assessment, the establishment of milk hygiene standard, and information to the producers and consumers about the potential health from milk. However innovations could only be accepted if they are cost-effective and affordable to all parts involved.

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