Microbiological quality of commercial dairy products

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The purpose of this research was to assess the hygienic properties of commercially available dairy foods. The products surveyed included liquid milks (pasteurized and UHT-treated), cultured dairy products (kefir, cultured buttermilk, sour cream, yogurt, probiotic fermented milks), cheeses (quarg products, soft, semi-hard, hard, and extra hard cheeses made from bovine, caprine, and ovine milk), processed cheeses, butters, butter creams, dried milks, and ice creams. A total of 320 samples were purchased from food stores located in the western part of Hungary. Upon collection, all products were taken to the laboratory and were stored as required until analysis. Although none of the samples tested contained Salmonella spp. or Listeria monocytogens, approximately 14% of them failed to meet the legal requirements in terms of overall hygienic quality. The share of non-compliant samples was especially high among cheeses.

Keywords hygienic quality; dairy food

1. Introduction

Food spoilage is an enormous economic problem worldwide. Through microbial activity alone, approximately one-fourth of the world's food supply is lost [1]. Milk is a highly nutritious food that serves as an excellent growth medium for a wide range of microorganisms [2, 3]. The microbiological quality of milk and dairy products is influenced by the initial flora of raw milk, the processing conditions, and post-heat treatment contamination [4]. Undesirable microbes that can cause spoilage of dairy products include Gram-negative psychrotrophs, coliforms, lactic acid bacteria, yeasts, and molds. In addition, various bacteria of public health concern such as *Salmonella* spp., *Listeria monocytogenes*, *Campylobacter jejuni*, *Yersinia enterocolitica*, pathogenic strains of *Escherichia coli* and enterotoxigenic strains of *Staphylococcus aureus* may also be found in milk and dairy products [5]. For this reason, increased emphasis should be placed on the microbiological examination of milk and dairy foods. Microbiological analyses are critical for the assessment of quality and safety, conformation with standards and specifications, and regulatory compliance [6].

In Hungary, a very comprehensive set of microbiological reference criteria covering virtually all foods and including limits for an extensive range of indicators and pathogens was issued by the Ministry of Health in 1998. This official document entitled "Decree No. 4/1998 (XI. 11.) EüM on the acceptable levels of microbiological contamination in foods" [7] is based on ICMSF and FAO principles in that it includes sampling plans and identifies the criteria for acceptance or rejection of a lot. Altogether 26 food groups have mandatory criteria and the number or type of microorganisms for which there are limits for any particular food varies from one to nine. Divided into nine subgroups, milk and milk products constitute one of the 26 groups formed. As of 2003, in terms of dairy foods, this legal document was replaced by another one titled "Decree No. 1/2003 (I. 8.) FVM-ESzCsM on the food hygienic conditions for production and placing on the market of raw milk, heat-treated milk and milk-based products" [8], which is identical in content with the EU Milk Hygiene Directive 92/46/EEC [9].

In the international literature, there is a relative scarcity of data pertaining to the levels of spoilage organisms and pathogens in commercially available milk products. Therefore, the aim of this study was to monitor the hygienic quality of milk and dairy foods sold to the general public in Hungary.

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2. Materials and Methods

Table 1 Microbiological reference criteria for dairy foods in Hungary.

Product	Microorganism (group)	n	c	m	M	n	c	m	M
		Before 2003 [7]				As of 2003 [8]			
Pasteurized milk	*Salmonella* spp.	5	0	–	0/25g	5	0	–	0/25g
	Listeria monocytogenes	5	0	–	0/25g	5	0	–	0
	Staphylococcus aureus	5	2	1	10	–	–	–	–
	Enterococcus faecalis	5	2	10	10^2	–	–	–	–
	Coliforms	5	1	1	10	5	2	1	5
	Total plate count	5	2	10^4	10^5	5	2	5.0×10^4	10^5
UHT milk	Total plate count	5	0	–	0	1	0	–	10/0.1g
Cultured dairy product[a]	*Salmonella* spp.	10	0	–	0/25g	5	0	–	0/25g
	Listeria monocytogenes	–	–	–	–	5	0	–	0
	Staphylococcus aureus	5	2	1	10	–	–	–	–
	Molds	5	2	10^2	5.0×10^3	–	–	–	–
Cheese	*Salmonella* spp.	5	0	–	0/25g	5	0	–	0/25g
	Listeria monocytogenes	5	0	–	0/25g	5	0	–	0/25g[b]
	Staphylococcus aureus	5	0	–	0	5	2	$10^3/10^2/10^c$	$10^4/10^3/10^{2c}$
	Escherichia coli	–	–	–	–	5	2	$10^4/10^2/-^c$	$10^5/10^3/-^c$
	Coliforms	5	2	10^d	10^{2d}	5	2	$-/10^4/-^c$	$-/10^5/-^c$
	Sulfite-reducing clostridia	5	1	10	10^2	–	–	–	–
	Molds	5	1	10	10^2	–	–	–	–
Processed cheese	*Salmonella* spp.	5	0	–	0/25g	5	0	–	0/25g
	Listeria monocytogenes	–	–	–	–	5	0	–	0
	Staphylococcus aureus	5	0	–	0	–	–	–	–
	Total plate count	–	–	–	–	5	2	5.0×10^4	10^5
Butter and butter product	*Salmonella* spp.	5	0	–	0/25g	5	0	–	0/25g
	Listeria monocytogenes	5	0	–	0	5	0	–	0
	Coliforms	–	–	–	–	5	2	1	10
Dried milk	*Salmonella* spp.	10	0	–	0/25g	10	0	–	0/25g
	Listeria monocytogenes	5	0	–	0/25g	5	0	–	0
	Staphylococcus aureus	10	2	1	10	5	2	10	10^2
	Coliforms	5	2	1	10	5	2	1	10
	Total plate count	–	–	–	–	5	2	5.0×10^4	10^5
Ice cream	*Salmonella* spp.	10	0	–	0/25g	5	0	–	0/25g
	Listeria monocytogenes	–	–	–	–	5	0	–	0
	Staphylococcus aureus	5	1	10^2	10^3	5	2	10	10^2
	Escherichia coli	5	1	10	10^2	–	–	–	–
	Coliforms	–	–	–	–	5	2	10	10^2
	Total plate count	–	–	–	–	5	2	10^5	5.0×10^5

n: The number of sample units to be examined from a lot of dairy food; c: The maximum allowable number of marginally acceptable sample units; m: Expressed in CFU/g, it represents an acceptable level and values above it are marginally acceptable or unacceptable in terms of the sampling plan; M: Expressed in CFU/g unless otherwise stated, it is a microbiological criterion which separates marginally acceptable quality from defective quality.
[a] According to regulatory criteria in effect before 2003 [7], quarg and quarg products belonged to this group of dairy foods; [b] Not applicable to hard cheese, for which M = 0 CFU/g; [c] Cheese made from raw milk or thermized milk / Soft cheese made from heat treated milk / Fresh cheese; [d] For soft cheese m = 10^4 and M = 10^5.

From 2001 through 2006, a total of 320 samples of milk products were purchased from food stores located in the western part of Hungary. Duplicate (i.e., two identical) samples were collected from each type of product at each sampling session. Either of them was examined right after purchase whereas the other one was stored at the required temperature and analyzed immediately before the end of shelf life. The products tested included liquid milks (pasteurized and UHT-treated), cultured dairy products (kefir, cultured buttermilk, sour cream, yogurt, probiotic fermented milks), cheeses (quarg products, soft, semi-hard, hard, and extra hard cheeses made from bovine, caprine, and ovine milk), processed cheeses, butters, butter creams, dried milks, and ice creams.

Salmonella spp. were detected and organisms indicating poor hygiene (*S. aureus*, *E. coli*, *Enterococcus faecalis*) and indicator organisms (total plate count, coliforms, mesophilic sulfite-reducing clostridia, molds) were enumerated according to LMBG §35, the German collection of official methods for the investigation of foods [10]. Detection of *L. monocytogenes* was performed following the DIN EN ISO 11290-1 protocol [11].

In the case of samples taken before 2003, the data obtained were compared to the criteria contained in Decree No. 4/1998 (XI. 11.) EüM on the acceptable levels of microbiological contamination in foods [7], and as of 2003, our results were evaluated on the basis of Decree No. 1/2003 (I. 8.) FVM-ESzCsM on the food hygienic conditions for production and placing on the market of raw milk, heat-treated milk and milk-based products [8] (Table 1).

3. Results and Discussion

None of the pasteurized milk samples surveyed contained detectable levels of coliforms (<0.3 MPN/cm^3), *E. faecalis* (<1 CFU/cm^3), *S. aureus* (<1 CFU/cm^3), *Salmonella* spp. (0 CFU/25 cm^3), or *L. monocytogenes* (0 CFU/25 cm^3), and all the product units tested at the time of purchase had microbial counts lower than 10^3 CFU/cm^3 whereas the total plate counts of 14.3% of the samples examined at the end of shelf life exceeded the M value of 10^5 CFU/cm^3 (Table 2).

Table 2 Hygienic quality of commercial liquid milks.

Product	Tested	No. of samples tested	Non-compliance (%)		
			in total	because of	
				TPC	other microbe
Pasteurized milk	after purchase	7	0	0	0
	at expiry	7	14.3	14.3	0
UHT milk	after purchase	10	0	0	0
	at expiry	10	10.0	10.0	0
Total	after purchase	17	0	0	0
	at expiry	17	11.8	11.8	0

TPC: Total plate count.

These results are considerably better than those reported by Szakály et al. [12], who found that 70.6% of pasteurized milks failed to comply with regulatory standards, largely due to the elevated counts of coliforms and, to a lesser extent, to that of aerobic mesophilic microbes. The initial microbiota of freshly pasteurized milk, which consists primarily of thermoduric bacteria and spores, is dependent on the microbial population of the raw milk before pasteurization. Most thermoduric bacteria grow slowly in refrigerated milk and are generally outgrown by Gram-negative psychrotrophic species that gain entry primarily as post-pasteurization contaminants [13]. However, in the absence of psychrotrophic bacteria or if large numbers of thermoduric bacteria survive pasteurization, certain thermodurics, particularly psychrotrophic sporeforming *Bacillus* spp., can grow and cause spoilage [14].

Table 2 also indicates that the non-compliance percentage of UHT milks was similar to that of pasteurized milks. Although *L. monocytogenes*, *Salmonella* spp., or coliform organisms were not

recovered from any of the samples tested, total plate counts exceeded regulatory standards in one out of 10 product units at the end of shelf life.

Cultured dairy products were found to be of high hygienic quality since they did not contain any type of microorganism for which there were limits in Decree No. 4/1998 (XI. 11.) EüM [7] (Table 3). In a normal fermentation, a final pH of 4.5 or less is developed in cultured milk products. This low pH prevents the growth of most spoilage and pathogenic organisms [4]. It is also worth noting that none of the kefir samples examined immediately before the stated expiry date had viable yeast counts of at least 10^4 CFU/g, a level required by Codex Alimentarius Hungaricus [15]. Even more surprisingly, approximately half of the kefir samples were completely devoid of yeasts that compose the essential microbiota of kefir (data not shown).

Table 3 Hygienic quality of commercial cultured dairy products.

Product	Tested	No. of samples tested	Non-compliance (%)			
			in total	because of		
				molds	SA	Sal
Kefir	after purchase	7	0	0	0	0
	at expiry	7	0	0	0	0
Cultured buttermilk	after purchase	7	0	0	0	0
	at expiry	7	0	0	0	0
Sour cream	after purchase	7	0	0	0	0
	at expiry	7	0	0	0	0
Yogurt	after purchase	7	0	0	0	0
	at expiry	7	0	0	0	0
Probiotic fermented milk	after purchase	8	0	0	0	0
	at expiry	8	0	0	0	0
Total	after purchase	36	0	0	0	0
	at expiry	36	0	0	0	0

SA: *Staphylococcus aureus*; Sal: *Salmonella* spp.

As is illustrated in Table 4, quarg products, which belong to the fresh or acid-coagulated cheese group, were of relatively high hygienic quality compared to the other cheese varieties tested. Out of 14 samples, half of which were examined after purchase and the other half just before the expiration of shelf life, only two failed to comply with regulatory standards due to mold counts exceeding the M value of 5.0×10^3 CFU/g. High-moisture cheeses such as quarg are prone to spoilage by various microorganisms, including molds, that enter as post-pasteurization contaminants [13].

Table 4 Hygienic quality of commercial cheeses.

Product		No. of samples tested	Non-compliance (%)					
			in total	because of				
				mold	Clo	Col	EC	SA
Quarg	ap[5]	7	14.3	14.3	–	–	–	0
	ae[6]	7	14.3	14.3	–	–	–	0
Soft cheese	ap[5]	28	42.9	7.1	0	21.4	10.7	17.9
	ae[6]	28	50.0	7.1	0	25.0	21.4	25.0
Semi-hard cheese	ap[5]	19	21.1	21.1	0	0	–	0
	ae[6]	19	5.3	0	0	0	–	5.3
(Extra-)hard cheese	ap[5]	9	33.3	0	33.3	0	–	0
	ae[6]	9	33.3	0	0	33.3	–	0
Total	ap[5]	63	31.7	11.1	4.8	9.5	4.8	7.9
	ae[6]	63	30.2	4.8	0	15.9	9.5	12.7

Clo: Mesophilic sulfite-reducing clostridia; Col: coliforms; EC: *Escherichia coli*; SA: *Staphylococcus aureus*; ap: after purchase; ae: at expiry.

Of all the rennet-coagulated cheese varieties, soft cheeses had the poorest hygienic quality with as many as half of the samples tested at the end of shelf life exceeding regulatory standards for mold, *S. aureus*, coliform, or *E. coli* counts (Table 4). In low-acid, soft or semi-soft, surface-ripened cheese, fecal coliforms are commonly found [16]. *Staphylococcus aureus* normally declines during the ripening stage, but if high numbers are reached during cheese making, enterotoxins may persist in the cheese. When there is reason to suspect possible public health concerns because of *Staphylococcus*, it would be advisable to test for staphylococcal toxins [4]. The hard and extra-hard cheese types showed a non-compliance rate of 33.3% regardless of sampling time. As seen in Table 4, semi-hard cheeses were the only rennet-coagulated cheese group which had microbiological properties comparable to those of the other commercial dairy foods monitored in this study. All things considered, only approximately 70% of the cheese samples collected met the acceptance criteria for microbiological quality and safety.

Table 5 shows that the processed cheese samples tested immediately after purchase were of excellent microbiological quality whereas, at the end of shelf life, 10% of the product units failed to meet regulatory standards for bacterial counts. The reader should also be aware that *S. aureus* were present in two samples, one of which had staphylococcal counts as high as 3.0×10^5 CFU/g, however, Decree No. 1/2003 (I. 8.) FVM-ESzCsM [8] defines no mandatory criteria for this bacterial group in the case of processed cheese. Similar to what was experienced with other product groups, none of the processed cheese samples surveyed contained foodborne pathogens at detectable levels.

Table 5 Hygienic quality of commercial processed cheeses.

Product	Tested	No. of samples tested	Non-compliance (%)		
			in total	because of	
				TPC	other microbe
Processed cheese	after purchase	10	0	0	0
	at expiry	10	10.0	10.0	0

TPC: Total plate count.

The microbiota of butter reflects the quality of the cream, the sanitary conditions of the equipment used to manufacture the butter, and the environmental and sanitary conditions during packaging and handling [4]. The microbiological properties of our butters and butter creams were in complete compliance with the criteria established by Decree No. 4/1998 (XI. 11.) EüM [7] (Table 6). However, it should be mentioned that this product group was required to be tested for the presence of only a limited range of pathogens such as *Salmonella* spp. and *L. monocytogenes*. If Decree No. 1/2003 (I. 8.) FVM-

ESzCsM [8] had been in effect at the time of our trials, 75% of butter samples should have been rejected because of the presence of coliforms whereas butter creams would have shown the same compliance rate (i.e., 100%).

Table 6 Hygienic quality of commercial butters and butter creams.

Product	Tested	No. of samples tested	Non-compliance (%)		
			in total	because of	
				LM	*Salmonella* spp.
Butter	after purchase	8	0	0	0
	at expiry	8	0	0	0
Butter cream	after purchase	8	0	0	0
	at expiry	8	0	0	0
Total	after purchase	16	0	0	0
	at expiry	16	0	0	0

LM: *Listeria monocytogenes*.

None of the butter cream samples collected contained detectable levels of coliforms, *S. aureus*, molds, *Salmonella* spp., or *L. monocytogenes*, and their yeast and bacterial counts were also very low. Butter cream is made from cream of increased solids-non-fat levels using double-stage homogenization, fermentation by lactic acid bacteria, and heat-treatment of the finished product, which thus has a fat content of at least 37%, total solids content of over 45% and a pH value of 4.0 to 4.6. Unlike butter, butter cream is a product in the form of an oil-in-water type emulsion [17]. The microbiological stability of butter creams throughout shelf life was ensured by post-heat treatment at low pH and aseptic packaging of the finished product. Our results are consistent with those of Szakály et al. [12], who found no sample exceeding regulatory standards for microbiological properties out of 8 butter cream samples surveyed.

Most dried dairy products are used as ingredients of other foods and are subject to further processing. Yet, dried milks must be considered sensitive products from a public health aspect because they are often consumed after reconstitution without additional heating [4]. The results in Table 7 indicate that 12.5% of the milk powder samples tested immediately prior to the stated expiry date had coliform counts exceeding regulatory standards. Because coliform bacteria are reduced to very low levels during preheating [18], their presence in dried milk products indicates contamination from equipment or the environment during or after manufacture [4]. In this study, the total plate counts of milk powders examined after purchase ranged from 5.3×10^3 to 2.2×10^4 CFU/g and, due to oxidative destruction of bacterial cells [19], showed a downward tendency during storage. These findings are similar to those of Szakály et al. [12] who reported that all of 70 samples of dried milks surveyed had acceptable bacteriological quality.

Table 7 Hygienic quality of commercial dried milks.

Product	Tested	No. of samples tested	Non-compliance (%)		
			in total	because of	
				coliforms	other microbe
Dried milk	after purchase	8	0	0	0
	at expiry	8	12.5	12.5	0

None of the ice cream samples taken contained detectable levels of *L. monocytogenes* or *Salmonella* spp., and the *S. aureus* counts were also below the detection limit. Although coliform counts exceeded the M value of 10^2 CFU/g in 10% of the cases in both groups (Table 8), all samples collected met the regulatory standards for total plate counts. The presence of coliforms in frozen dairy products is an indication of post-pasteurization contamination, which can occur from poorly cleaned equipment, air

incorporation, poor use of product rerun, and personnel [20]. Besides, addition of flavors, coloring agents, and ingredients such as fruits, nuts, and chocolate chips to the mix after pasteurization can also be a source of contamination [4]. Our results are superior to those previously reported for ice creams commercialized in various parts of the world, where non-compliance percentages ranged from 33.3% to well over 50% [21–24].

Table 8 Hygienic quality of commercial ice creams.

Product	Tested	No. of samples tested	Non-compliance (%)		
			in total	because of	
				coliforms	other microbe
Ice cream	after purchase	10	10.0	10.0	0
	at expiry	10	10.0	10.0	0

In Hungary, the quality of commercial dairy products is monitored on a regular basis by both the national veterinary and food authorities [25] and the Dairy Product Board [26]. As shown in Table 9, roughly 14% of the samples examined in our study failed to meet required regulatory standards in terms of overall hygienic quality. These results are similar to those reported by Unger [26] and Wojtoń and Różańska [27], who found non-compliance rates of 16.6% and 17.7%, respectively, among commercially available dairy foods in Central and Eastern Europe. In another study by Pfleger [28], only yogurts and semi-hard cheeses proved to be of excellent quality whereas for the other products tested good hygienic quality could only be found in 50% to 90% of the samples.

Table 9 Hygienic quality of dairy foods commercialized in Hungary.

Product	Tested	No. of		Non-compliance (%)
		samples tested	non-compliant samples	
Dairy food	after purchase	160	21	13.1
	at expiry	160	24	15.0
	in total	320	45	14.1

4. Conclusions

A relatively high percentage of dairy foods monitored over a 6-year period were contaminated with microbes at levels exceeding regulatory limits. Although pathogenic organisms were not detected in any of the samples tested, the hygienic quality of commercial milk products must be improved considerably, and this is especially true for cheese.

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