Microbial quality of milk from grass based production systems and impact on milk powder quality

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Abstract

The microbial quality of bovine milk, produced on a pasture-based system on 67 dairy farms, and its influence on milk powder quality were evaluated. The diet of the cows consisted mainly of perennial ryegrass with an additional 2.0 kg DM cow^{-1} day^{-1} of concentrates. Milk was sampled from farm bulk tanks, as well as from the 11 collection tankers, whole milk (WMS) and skim milk (SMS) silos. Skim milk powder (SMP) was also sampled. The average total bacterial count (TBC) for the farm milk samples was 3.78 ± 0.08 log_{10} cfu ml^{-1}, which was similar to that observed in the tankers (3.90 ± 0.41 log_{10} cfu ml^{-1}) and increased in the WMS (5.89 ± 0.02 log_{10} cfu ml^{-1}). Pasteurisation decreased TBC (SMS: 2.61 ± 0.20 log_{10} cfu ml^{-1}), while evaporation and drying resulted in further reductions of TBC in SMP (2.36 ± 0.09 log_{10} cfu g^{-1}). Thermal processes were not efficient in reducing thermoduric bacterial counts (LPC), which did not vary greatly from farm (0.90 ± 0.11 log_{10} cfu ml^{-1}) to SMS (1.85 ± 0.10 log_{10} cfu ml^{-1}). In conclusion, milk of good microbial quality can be produced from grass-based systems, resulting in high quality milk powder.

Keywords: milk quality, milk powder, pasture-based systems, microbiological quality

Introduction

Ireland is the tenth largest dairy exporter in the world, supplying dairy products to 130 countries. The Irish industrial milk production is currently expanding due to the end of the milk quotas and to the increase in demand for dairy products worldwide. The maintenance of high milk quality is essential to hold market share and produce dairy products in accordance with specific quality parameters. On Irish dairy farms, pasture-based seasonal calving is the main milk production system, coordinating the peak of the lactation period and milk production with grass growth peak. Farming systems that are pasture-based can contribute to the production of milk with high fat content (due to a diet rich in fibre) and high protein content. Such milk is rich in fatty acids, vitamins and volatile compounds (flavours, terpenes) favourable to human nutrition and health. In this study, the microbiological quality and composition of milk produced from pasture-based systems on 67 commercial dairy farms were evaluated and monitored throughout the milk powder manufacturing process, and the effect on the final product quality was evaluated.

Materials and methods

To undertake the manufacturing process within the factory, a minimum quantity of milk was required (296,003 l), which was supplied by a total of 67 dairy farms during the mid-lactation period (May, 2016). The dairy farms that participated in this study were located in the Kilkenny and Waterford regions of Ireland. The diet of the cows on the farms (Holstein-Friesian, 120 DIM) consisted mainly of perennial ryegrass with on average an additional 2.0 kg DM cow^{-1} day^{-1} of concentrates. The average milk volume collected from each farm was 4,418 l, which was stored in bulk tanks for an average of 48 h prior to tanker collection. Collection tankers (11) transported the milk from the farms (approximately 6 farms / tanker) to a commercial skim milk powder factory and the milk collected was stored in the whole milk silo (WMS) for approximately 5.5 h at 4.6 °C. Milk was then pasteurised (high temperature / short time treatment), cream was separated and skim milk was stored in the skim milk silo (SMS). The skim milk underwent evaporation and a spray-drying process to produce skim milk powder (SMP) (21,940 kg). Milk samples were collected from the top inlet of the 67 farm bulk tanks, collection tankers (11) and the WMS and SMS. During the start, middle and final stages of the spray dryer run, 9 × 25 kg bags of powder were collected. A representative sample was collected from each bag (300 g) and reconstituted using deionised water (1:10 dilutions). All samples were tested for total bacterial count (TBC), psychrotrophic (PBC), proteolytic (PROT), thermoduric (Laboratory pasteurisation count – LPC), thermophilic (THERM), presumptive *Bacillus cereus* (BAC) and sulphite-reducing *Clostridia* (SRC) bacterial counts, as well as fat, protein and lactose contents were also measured in the samples. Somatic cell count (SCC) was measured in all samples, except in the SMP samples.

Results and discussion

The TBC and PBC levels in the farm bulk tank milk samples varied from 2.48 to 4.97 $\log_{10}$ cfu ml^{-1} and from 2.84 to 4.67 $\log_{10}$ cfu ml^{-1}, respectively. The TBC levels were below the European limit (TBC: 5.00 $\log_{10}$ cfu ml^{-1}, EC no 853/2004) and below the typical limit applied by some Irish milk processors (4.70 $\log_{10}$ cfu ml^{-1}). Twelve farms had PBC levels higher than the European limit (PBC: 4.22 $\log_{10}$ cfu ml^{-1}), possibly due to the milk storage temperature within the bulk tanks, as low temperatures are favourable for the growth of psychrotrophs. The average PROT was below the limit suggested by Vyletelova *et al.* (2000) (4.65 $\log_{10}$ cfu ml^{-1}), at which proteolytic bacteria starts to produce high levels of heat-resistant enzymes. The LPC levels were below typical Irish milk processor specifications and varied from 2.70 to 3.00 $\log_{10}$ cfu ml^{-1}. Milk of good microbiological quality was produced on-farm, given that TBC, PBC, PROT and LPC are below the limits cited. The European legislation or dairy processors have no specifications for thermophilic bacteria in milk. The farm milk samples also had a low level of contamination with BAC (non-detected to 2.00 $\log_{10}$ cfu ml^{-1}) and SRC (non-detected to 1.00 $\log_{10}$ cfu ml^{-1}). The TBC, PBC, PROT and LPC levels in the collection tankers samples were also below the limits cited. The TBC, PBC and PROT levels were higher in the WMS than in the collection tanker samples, which could be due to the silo or transference equipment (pipes, pumps, filters) cleaning practices. The TBC was above the limit specified in legislation for milk prior to processing (5.48 $\log_{10}$ cfu ml^{-1}; EC no 853/2004). The temperature applied during pasteurisation (75 °C, 25 s) was effective in significantly reducing the TBC, PBC and PROT levels, as observed in the SMS samples. The subsequent processing, where high temperatures were applied, also contributed to further reductions in those bacterial counts, as observed in the SMP samples (Table 1). The LPC and THERM levels were similar in the WMS and SMS samples, indicating that pasteurisation was not efficient in reducing those bacteria numbers, possibly due to the high temperatures applied, which are favourable for the growth of thermoduric and thermophilic bacteria; also, spores can survive high temperatures. The highest bacterial counts in the SMP samples were LPC and THERM; however, THERM counts were below the industrial limit applied in the USA for milk powder (4.00 $\log_{10}$ cfu g^{-1}). The composition of the milk transported by the tankers was similar

Table 1. Average (± SD) total bacterial count (TBC), psychrotrophic (PBC), proteolytic (PROT), thermoduric (LPC) and thermophilic (THERM) bacterial counts of milk samples from the farm bulk tanks, collection tankers, whole milk silo (WMS) and skim milk silo (SMS), and of the skim milk powder (SMP) samples.

Samples	Bacterial counts ($\log_{10}$ cfu ml^{-1})				
	TBC	PBC	PROT	LPC	THERM
Farm bulk tanks	3.78 ± 0.08	3.74 ± 0.09	3.54 ± 0.17	1.26 ± 0.11	0.90 ± 0.11
Collection tankers	3.90 ± 0.41	3.70 ± 0.55	3.64 ± 0.35	1.38 ± 0.44	1.43 ± 0.68
WMS	5.89 ± 0.02	6.00	5.45 ± 0.62	1.55 ± 0.17	2.00 ± 0.14
SMS	2.61 ± 0.20	2.00	2.00	1.69 ± 0.07	1.85 ± 0.10
SMP[1]	2.36 ± 0.09	0.99 ± 0.48	1.24 ± 0.53	2.45 ± 0.09	3.63 ± 0.12

[1] Results given in $\log_{10}$ cfu g^{-1}.

to the composition of the raw milk collected from the corresponding farms, and no differences were noticed in the WMS, as expected (Table 2). After cream separation, the fat content in the SMS samples decreased, while the protein and lactose contents remained the same (Table 2). The average SCC in the farm milk samples was 135 ± 73 × 10^3 cells ml^{-1} (range: 36 to 342 × 10^3 cells ml^{-1}) and was below the European threshold limit (400 × 10^3 cells ml^{-1}). The average SCC in the tanker milk samples and WMS were similar: 139 ± 42 × 10^3 cells ml^{-1} and 126 ± 3 × 10^3 cells ml^{-1}, respectively. The SCC decreased in the SMS samples (98 ± 8 × 10^3 cells ml^{-1}), possibly due to the separation of somatic cells with the cream.

Table 2. Average (± SD) fat, protein and lactose contents of the milk samples from the farm bulk tanks, collection tankers, whole milk silo (WMS) and skim milk silo (SMS) and of the skim milk powder (SMP) samples.

Samples	Fat %	Protein %	Lactose %
Farm bulk tanks	3.76 ± 0.05	3.44 ± 0.02	4.89 ± 0.01
Collection tankers	3.76 ± 0.12	3:44 ± 0.06	4.90 ± 0.04
WMS	3.85 ± 0.01	3.42 ± 0.01	4.88 ± 0.03
SMS	0.08 ± 0.05	3.54 ± 0.01	5.08 ± 0.01
SMP (reconstituted)	0.09 ± 0.03	3.45 ± 0.05	4.88 ± 0.08

Conclusion

Milk of good microbiological and compositional quality was produced from grass-based systems, contributing to the production of good quality milk powder. The differences in bacterial counts between production stages are indications of the growth potential of the bacteria in the milk, or even an indication of possible contamination sources. Also, the reduction of bacterial counts is evidence of the effectiveness of pasteurisation. This study can aid industry in the development of new sanitation procedures, process controls or optimisation of processes parameters and practices to control bacterial numbers in order to ensure the consistent production of safe high-quality dairy products.

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References

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