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The effect of storage temperature and duration on the microbial quality of bulk tank milk

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ABSTRACT

The dairy industry in Ireland is currently undergoing a period of expansion and, as a result, it is anticipated that milk may be stored in bulk tanks on-farm for periods greater than 48 h. The objective of this study was to investigate the effects of storage temperature and duration on microbial quality of bulk tank milk when fresh milk is added to the bulk tank twice daily. Bulk tank milk stored at 3 temperatures was sampled at 24-h intervals during storage periods of 0 to 96 h. Bulk tank milk samples were analyzed for total bacterial count (TBC), psychrotrophic bacterial count (PBC), laboratory pasteurization count (LPC), psychrotrophic-thermoduric bacterial count (PBC-LPC), proteolytic bacterial count, lipolytic bacterial count, presumptive *Bacillus cereus*, sulfite-reducing *Clostridia* (SRC), and SCC. The bulk tank milk temperature was set at each of 3 temperatures (2°C, 4°C, and 6°C) in each of 3 tanks on 2 occasions during two 6-wk periods. Period 1 was undertaken in August and September, when all cows were in mid lactation, and period 2 was undertaken in October and November, when all cows were in late lactation. None of the bulk tank bacterial counts except the proteolytic count were affected by lactation period. The proteolytic bacterial count was greater in period 2 than in period 1. The TBC and PBC of milk stored at 6°C increased as storage duration increased. The TBC did not increase with increasing storage duration when milk was stored at 2°C or 4°C but the PBC of milk stored at 4°C increased significantly between 0 and 96 h. The numbers of proteolytic and lipolytic bacteria, LPC, or PBC-LPC in bulk tank milk were not affected by temperature or duration of storage. Presumptive *B. cereus* were detected in 10% of all bulk tank milk samples taken over the two 6-wk periods, with similar proportions observed in both. In bulk tank milk samples, a greater incidence of SRC was observed in period 2 (20%) compared with period 1 (3%). Milk produced on-farm with minimal bacterial contamination can be successfully stored at 2°C and 4°C for up to 96 h with little effect on its microbial quality.

Key words: raw milk, milk storage, storage temperature, total bacteria count, psychrotrophic bacteria

INTRODUCTION

The abolition of the European Union milk quota system in April 2015 will likely lead to a significant increase in milk production within the Irish dairy sector, and the national strategy anticipates an expansion of 50% by 2020 (DAFM, 2010). Because approximately 85% of milk produced in Ireland is exported as dairy products, further expansion in milk production will necessitate expansion of the dairy export market. However, the success of this expansion is reliant on the production of high quality milk to produce a wide range of top quality products (O'Brien et al., 2009).

Because of expansion, it is likely that bulk tank milk storage time will be extended on farms. European Union legislation specifies that milk produced and stored on-farm must be cooled to at least 8°C (when collected daily). In Ireland, milk is usually collected at 48-h intervals, but in spring and winter, the collection interval is often extended to 96 h. Milk processors request that milk be cooled to 2 to 4°C within 2 to 3 h of milking. Milk cooling has the largest electrical energy consumption on Irish dairy farms (Upton et al., 2013). Thus, there may be an economic incentive for farmers to cool and store milk at higher temperatures (e.g., at 6°C compared with 2°C), especially if milk is being stored for an extended duration.

Microbial tests such as the total bacteria count (**TBC**) and psychrotrophic bacterial count (**PBC**) are

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used to characterize raw milk quality and have been demonstrated to be affected by storage time and temperature. A study by Muir et al. (1978) showed that when milk was stored at 4°C, 6°C, and 8°C, the TBC increased from a starting value of 3.2×10^3 cfu/mL, to 5.2×10^5 at 4°C, 3.3×10^6 at 6°C, and 1.0×10^7 at 8°C, after 105 h of storage. Meanwhile, psychrotrophic bacterial growth remained in the lag phase for at least part of the first 48-h period when milk was stored at 4°C and 6°C, whereas immediate growth was observed in milk stored at 8°C. A further study by Griffiths et al. (1987) showed that the time taken for the PBC in milk to increase from 2.6×10^2 to $>10^6$ cfu/mL was 2.9 and 5.0 d when milk was stored at 6°C and 2°C, respectively.

Spoilage bacteria such as proteolytic and lipolytic bacteria can also grow in milk during storage (Celestino et al., 1996) and alter the quality and shelf life of the milk. Such bacteria are capable of producing proteases and lipases that can break down milk protein and fat, leading to casein damage and the development of rancid and bitter flavors (Muir, 1996).

Laboratory pasteurization count (**LPC**) as well as thermoduric and psychrotrophic-thermoduric (**PBC-LPC**) bacteria can survive pasteurization and multiply during processing and can contribute to milk spoilage (Fromm and Boor, 2004). Two bacterial groups that are capable of surviving pasteurization and that can cause illness when ingested in large numbers are *Bacillus cereus* (aerobic spore-formers) and sulfite-reducing *Clostridia* (**SRC**; anaerobic spore-formers). The numbers of *B. cereus* and SRC present in milk are closely monitored during the manufacture of infant milk formula due to the possibility of toxin production and the vulnerability of its consumers. Thus, limiting the exposure of raw milk to contamination with *B. cereus* and SRC at the farm level is necessary.

Although previous studies have investigated microbial growth in milk during storage, those studies have been laboratory-based (Griffiths et al., 1987; Wiking et al., 2002; Malcarne et al., 2013) and may not entirely reflect on-farm conditions. The on-farm scenario involves the addition of warm fresh milk at each milking, which is blended with the cooled milk present in the bulk tank. The effect of storage conditions on the microbial quality of such blended milk has yet to be investigated and is likely to be more representative of what occurs on commercial farms than previous laboratory-based experiments.

The objective of this study was to investigate the effects of milk storage temperature and storage time on the microbial quality of bulk tank milk when fresh milk was added twice daily throughout the storage period.

MATERIALS AND METHODS

Experimental Design

The experiment was conducted at the Animal and Grassland Research and Innovation Centre, Teagasc, Moorepark, Cork, Ireland, using milk produced from spring-calving dairy cows. Milk production over two 6-wk periods was studied; period 1 extended from August 11 to September 26, and period 2 extended from October 13 to November 21. During period 1 and the first 4 wk of period 2, the cows were outdoors consuming a diet of grass. During the remaining 2 wk of period 2, the cows were partially housed indoors during times of heavy rainfall on cubicles fitted with rubber mats that were bedded with lime, and they consumed a diet consisting of approximately 50% grazed grass and 50% grass silage. Milk was harvested on 48 occasions during each period. At each milking, before cluster attachment, teats were disinfected with polymeric biguanide hydrochloride (Super Cow Teat Foam, Milk Solutions Ltd., Kilworth, Co. Cork, Ireland) and dried using individual paper towels. Cows were milked twice a day at 10- and 14-h intervals in a 30-unit side-by-side milking parlor. The milk was transferred from the cluster to the mid-level milk-line (72 mm, internal diameter) in 16-mm (internal diameter) milk tubes, with a milk lift of 1.5 m, and from there to the receiver jar. The clusters were automatically removed as directed by the electronic milk meters when the milk flow rate decreased to 0.2 kg/min with a delay time of 20 s.

The milk was pumped from the receiver jar through a 48-mm stainless steel pipe, under laminar flow conditions using a variable speed milk pump. After each milking occasion, the milking equipment was rinsed with water (14 L/milking unit). This was followed by a hot (65 to 75°C) liquid detergent sterilizer (Liquid Gold, Dairymaster, Causeway, Kerry, Ireland) wash (9 L/unit) that was left to circulate for 8 to 10 min. Immediately after the detergent sterilizer wash, the milking equipment was rinsed twice, with the final rinse containing peracetic acid (0.3–0.5%). Once a week, an acid-descale (Extra-Strong Descaler, Dairymaster) washing cycle was incorporated into the milking regimen before the detergent cycle.

Three identical bulk milk tanks with a capacity of 4,000 L (Swiftcool, Dairymaster) were used in this study. Each tank was fitted with a 5.5-Hp condensing unit and a single-stage plate cooler (37 plates). Data on milk temperature, desired milk temperature setting, time of day, and milk volume in the tank were displayed on each tank. Each tank was set at each of the 3 temperatures (2°C, 4°C, and 6°C) on 2 occasions