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The effect of different precooling rates and cold storage on milk microbiological quality and composition

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ABSTRACT

The objective of this study was to measure the effect of different milk cooling rates, before entering the bulk tank, on the microbiological load and composition of the milk, as well as on energy usage. Three milk precooling treatments were applied before milk entered 3 identical bulk milk tanks: no plate cooler (NP), single-stage plate cooler (SP), and double-stage plate cooler (DP). These precooling treatments cooled the milk to 32.0 ± 1.4°C, 17.0 ± 2.8°C, and 6.0 ± 1.1°C, respectively. Milk was added to the bulk tank twice daily for 72 h, and the tank refrigeration temperature was set at 3°C. The blend temperature within each bulk tank was reduced after each milking event as the volume of milk at 3°C increased simultaneously. The bacterial counts of the milk volumes precooled at different rates did not differ significantly at 0 h of storage or at 24-h intervals thereafter. After 72 h of storage, the total bacterial count of the NP milk was 3.90 ± 0.09 $\log_{10}$ cfu/mL, whereas that of the precooled milk volumes were 3.77 ± 0.09 (SP) and 3.71 ± 0.09 (DP) $\log_{10}$ cfu/mL. The constant storage temperature (3°C) over 72 h helped to reduce bacterial growth rates in milk; consequently, milk composition was not affected and minimal, if any, proteolysis occurred. The DP treatment had the highest energy consumption (17.6 ± 0.5 Wh/L), followed by the NP (16.8 ± 2.7 Wh/L) and SP (10.6 ± 1.3 Wh/L) treatments. This study suggests that bacterial count and composition of milk are minimally affected when milk is stored at 3°C for 72 h, regardless of whether the milk is precooled; however, milk entering the tank should have good initial microbiological quality. Considering the numerical differences between bacterial counts, however, the use of the SP or DP precooling systems is recommended to maintain low levels of bacterial counts and reduce energy consumption.

Key words: milk precooling, milk microbiological quality, energy, milk storage

INTRODUCTION

Milk cooling and refrigerated storage are necessary after milking to reduce bacterial growth rates. Milk leaves the udder at approximately 35°C, which is a favorable temperature for bacterial growth (Walstra et al., 2006). Thus, the microbial load could increase rapidly if milk is maintained at that temperature. According to Holm et al. (2004), cooling milk rapidly (below 6°C) is necessary to avoid the multiplication of microorganisms, especially psychrotrophs, which can grow at refrigeration temperatures but have optimal and maximal growth temperatures at >15 and 20°C, respectively (Moyer and Morita, 2007). Thus, the precooling of milk (before it enters the bulk tank) could further reduce the bacterial growth rate. A further possible benefit of precooling milk is the reduction of energy costs on-farm (Murphy et al., 2013).

The equipment used to precool milk consists of plate heat exchangers incorporating stainless steel plates in a sandwich arrangement, in which milk and cooling water flow in opposite directions through the spaces between alternate plates (Wang et al., 2007). This system may have 1 or 2 cooling stages, in which well water and well and chilled waters are used in the first and second stages, respectively. O'Connell et al. (2016) observed only a minimal increase in milk bacterial count over time when fresh milk from each milking event was precooled using a single-stage plate cooler before being added to the bulk milk tanks twice daily.

Total bacterial count (**TBC**) is the main test used by milk processors to assess milk microbiological quality and it quantifies aerobic mesophilic bacteria in milk. In conjunction with TBC, the psychrotrophic bacterial count (**PBC**) is used to assess the hygiene quality of milk and is an indicator of hygiene conditions on-farm (Harding, 1995; Robinson, 2002). Milk cooling reduces the growth rate of mesophilic and psychrotrophic bacteria, the optimum growth temperatures of which are

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between 20 and 45°C and <7°C, respectively (Frank and Yousef, 2004; Willey et al., 2008). Thermoduric and thermophilic bacteria are the other relevant groups of bacteria that are measured in milk. These bacteria are important because they can survive thermal treatments such as those frequently applied in dairy processing to reduce bacterial numbers (e.g., pasteurization; Murphy et al., 1999; Robinson, 2002). The main sources of those bacteria are in the cows' environment, because their vegetative cells and spores can be present in feed, forage, bedding material, dust, feces and soil (Scheldeman et al., 2005; Gleeson et al., 2013). *Clostridium perfringens* and *Clostridium botulinum* are the pathogenic thermoduric bacteria of most relevance to the dairy industry because of their heat-resistant spores and toxins (Wrigley, 1994; Fernandes, 2009).

Some mesophilic, psychrotrophic, thermoduric, and thermophilic bacterial strains have the ability to produce lipases and proteases. These enzymes hydrolyze fat and protein, resulting in sensorial defects and altering the physico-chemical properties and processability of milk (Chen et al., 2003; Deeth, 2006). Lipolytic activity produces flavors described as rancid and bitter (Deeth, 2006) and could, for example, result in loss of foaming and creaming ability during butter manufacture (Shelley et al., 1987). Celestino et al. (1997) reported that reconstituted UHT milk powder manufactured using 4-d-old raw milk had rancid and bitter flavors compared with UHT milk powder produced using fresh raw milk, probably due to bacterial protease and lipase activity. Therefore, the control of bacterial numbers in milk helps to preserve milk functionality, allowing the production of a range of dairy products in accordance with specific quality parameters.

The aim of this study was to investigate the effect of precooling milk at different rates on the microbiological quality and composition of milk, as well as on energy usage. This study was conducted in a manner that mimicked on-farm milk production conditions: morning and evening milkings, similar milk storage conditions, and use or not of precooling systems.

MATERIALS AND METHODS

Experimental Design

This experiment was carried out in the dairy parlor at the Teagasc Animal and Grassland Research and Innovation Centre, Moorepark, Cork, Ireland. Spring-calving dairy cows (n = 210) were milked in a 30-unit side-by-side milking parlor, twice daily over two 3-wk periods, with milking commencing at 0700 and 1430 h. Period 1 extended from June 13 to July 2, 2016, and period 2 extended from July 25 to August 13, 2016. Before milking, cows' teats were washed and disinfected with chlorhexidine foam teat cleaner (Deosan Teatfoam Advance AG104, Sealed Air, Johnson Diversey Ltd., Dublin, Ireland) and dried using individual paper towels. The milk was transferred from clusters through 16-mm (internal diameter) milk tubes to a mid-level milk line (72 mm, internal diameter), with a milk lift of 1.5 m. The milk was collected in a receiver jar and pumped through a 48-mm stainless steel pipe, using a variable speed milk pump, to the bulk milk tanks (Figure 1). Once the milk flow rate dropped to 0.2 kg/min, clusters were automatically removed, with a delay time of 20 s. A system to individually wash and disinfect each cluster between each individual cow milking (Cluster Cleanse, Dairymaster, Causeway, Kerry, Ireland) was used. After each milking, the milking equipment was rinsed with water (14 L per milking unit), followed by a hot (75°C) liquid detergent sterilizer wash (Liquid Gold, Dairymaster) circulated for 8 to 10 min in the milk line. Following this, the milking equipment was rinsed twice, and the final rinse contained peracetic acid (0.3–0.5% concentration). An acid-descale (Extra-strong descaler, Dairymaster) was incorporated into the wash regime before the detergent cycle once a week.

The volume of milk collected during each milking was distributed equally into 3 identical bulk milk tanks. The milk line for each bulk tank was fitted with shut-off valves, which were used to control the milk flow rate and guarantee an equal distribution of milk to the tanks. Each bulk tank had capacity of 4,000 L (Swiftcool, Dairymaster) and was fitted with a 5.5-Hp condensing unit. A screen on the front of each tank displayed the milk temperature, time, and milk volume. The milk was cooled to 3°C within the tanks and stored for up to 72 h from once the first milking entered the tank. Approximately 800 and 500 L of milk were added to each bulk milk tank during the morning and afternoon milkings, respectively. At the end of each 72-h storage period, the milk was collected and the bulk milk tanks were washed using a hot detergent/sterilizer wash (50°C). This was followed by a cold-water rinse and an additional rinse containing peracetic acid. An acid-descale wash product was used at every third wash.

Before entering the bulk tanks, the milk underwent 1 of 3 precooling treatments: no precooling (**NP**), single-stage (**SP**), or double-stage (**DP**) plate cooling (Figure 1). In the NP treatment, the ground water line was closed; therefore, no precooling was undertaken in that treatment. In the SP treatment (37 plates), the milk exchanged heat with ground water at approximately 15°C. In the DP treatment (45 plates), the milk was cooled in 2 stages; in the first stage, ground water was used (at approximately 15°C) and in the second stage,