J. Dairy Sci. 96:8035–8046
http://dx.doi.org/10.3168/jds.2013-6657

Shelf life of pasteurized microfiltered milk containing 2% fat[1]

Z. Caplan and D. M. Barbano[2]
Northeast Dairy Foods Research Center Department of Food Science, Cornell University, Ithaca, NY 14853

ABSTRACT

The goal of this research was to produce homogenized milk containing 2% fat with a refrigerated shelf life of 60 to 90 d using minimum high temperature, short time (HTST) pasteurization in combination with other nonthermal processes. Raw skim milk was microfiltered (MF) using a Tetra Alcross MFS-7 pilot plant (Tetra Pak International SA, Pully, Switzerland) equipped with Membralox ceramic membranes (1.4 μm and surface area of 2.31 m^2; Pall Corp., East Hills, NY). The unpasteurized MF skim permeate and each of 3 different cream sources were blended together to achieve three 2% fat milks. Each milk was homogenized (first stage: 17 MPa, second stage: 3 MPa) and HTST pasteurized (73.8°C for 15 s). The pasteurized MF skim permeate and the 3 pasteurized homogenized 2% fat milks (made from different fat sources) were stored at 1.7 and 5.7°C and the standard plate count for each milk was determined weekly over 90 d. When the standard plate count was >20,000 cfu/mL, it was considered the end of shelf life for the purpose of this study. Across 4 replicates, a 4.13 log reduction in bacteria was achieved by MF, and a further 0.53 log reduction was achieved by the combination of MF with HTST pasteurization (73.8°C for 15 s), resulting in a 4.66 log reduction in bacteria for the combined process. No containers of MF skim milk that was pasteurized after MF exceeded 20,000 cfu/mL bacteria count during 90 d of storage at 5.7°C. The 3 different approaches used to reduce the initial bacteria and spore count of each cream source used to make the 2% fat milks did not produce any shelf-life advantage over using cold separated raw cream when starting with excellent quality raw whole milk (i.e., low bacteria count). The combination of MF with HTST pasteurization (73.8°C for 15 s), combined with filling and packaging that was protected from microbial contamination, achieved a refrigerated shelf life of 60 to 90 d at both 1.7 and 5.7°C for 2% fat milks.

Key words: microfiltration, shelf life, bacterial removal

INTRODUCTION

The fluid milk-processing industry would like the refrigerated shelf life of conventionally pasteurized HTST processed fluid milk to be longer than 14 to 21 d. Benefits of extended-shelf-life fluid milk include expanded distribution distances, fewer and more efficient processing plants, and increased product availability to consumers through convenience stores with slower product turnover rates. Extended shelf life could also deliver longer use time before spoilage once the consumer has purchased the product. Improved consumer perception of the quality of fluid milk products could lead to increased fluid milk consumption if consumers are less concerned with milk spoilage and more confident that fluid milk will retain its fresh taste longer.

United States regulatory standards require pasteurized fluid milk to have an SPC <20,000 cfu/mL (FDA, 2011). In practice, this criterion is applied on d 1 after pasteurization. From a consumer's perspective, the end of shelf life of fluid milk is the point at which they perceive the milk is no longer palatable based on sensory attributes such as flavor and aroma. Currently, bacterial spoilage is the limiting factor in extending the shelf life of conventionally pasteurized HTST processed fluid milk beyond 17 to 21 d (Boor, 2001; Martin et al., 2011). A published report found that in 1999, of 447 samples of commercially pasteurized milks, the percentages of samples with bacteria counts <20,000 cfu/mL during storage at 6°C were 61, 45, and 28 at 7, 10, and 14 d, respectively (Boor, 2001).

The Pasteurized Milk Ordinance defines legal minimal HTST pasteurization as heating milk to 72°C and holding at that temperature for at least 15 s (FDA, 2011). However, most milk processing plants use temperatures and holding times that exceed the minimum requirements (Douglas et al., 2000) to extend shelf life. One study found that pasteurization conditions of 79°C for 18 s, 79.4°C for 22 s, and 79.4°C for 28 s were being used at 3 New York state fluid milk processing plants (Fromm and Boor, 2004).

Received February 3, 2013.
Accepted May 5, 2013.

[1]Use of names, names of ingredients, and identification of specific models of equipment is for scientific clarity and does not constitute any endorsement of product by the authors, Cornell University, or the Northeast Dairy Foods Research Center.

[2]Corresponding author: dmb37@cornell.edu

Current shelf-life extension strategies include ultra-pasteurization (**UP**), UHT pasteurization, and microfiltration (**MF**). Ultra-pasteurized milk is heated to 138°C for at least 2 s, and generally has a shelf life of several weeks under refrigerated conditions (Boor and Nakimbugwe, 1998) when it is packaged nonaseptically. Although UP milk has a longer shelf life than HTST milk, a sensory study reported that the mean degree of liking of UP milk was rated slightly below "good" by children ages 6 to 11 (Chapman and Boor, 2001). The study also reported that children preferred HTST milk to UHT milk, and preferred UHT milk to UP milk, although the authors had no explanation of why the flavor quality of the UHT milk was rated better than the UP milk. The thermal process for UHT milk is the same thermal process as for UP milk, but the milk is aseptically packaged to avoid recontamination (Boor, 2001). The UHT milk is shelf stable and has an approximate shelf life of 6 mo (Boor, 2001). The advantage of UHT processing and aseptic packaging is that it allows the milk to be transported over longer distances and could provide milk to parts of the world without access to refrigeration. The UHT process is known to impart a cooked flavor to the milk (Horner et al., 1980), but over the years the UHT process has improved by using direct steam injection.

Other processes (e.g., bactofugation, MF, and gravity separation) offer alternatives to using high heat to reduce the bacteria count of raw milk. Bactofugation is a centrifugal process for removing spores from milk and has been applied mostly before cheese making to control late gas formation in cheeses (Fox et al., 2000). Microfiltration physically removes a portion of bacteria, spores, and somatic cells from skim milk. The Bactocatch commercial MF process for removing bacteria from skim milk, developed by Tetra Pak International SA (Pully, Switzerland), begins with the centrifugal removal of cream from raw whole milk using commercial continuous cream separator. The remaining skim milk is MF using a 1.4-μm ceramic membrane, and the bacteria are concentrated in the MF retentate (approximately 5% of the skim milk). A more recent version of this process further concentrates the MF retentate on a second MF apparatus, leading to permeation rates of proteins and TS >99.5 and 99.8%, and an MF retentate that is approximately 0.5% of the original volume of skim processed (Maubois and Schuck, 2005). The Bactocatch process uses cross-flow uniform transmembrane pressure to reduce membrane fouling (Sandblom, 1978). The MF retentate (concentrate of bacteria and spores) and cream undergo UP treatment and then can be combined with the low-bacteria MF skim permeate. The combination of MF permeate, cream, and MF retentate then receive a minimum HTST treatment.

Various studies have shown the effect of MF on reducing bacteria counts of skim milk. Kelly and Tuohy (1997) found that the total bacteria count of MF skim milk was, on average, 1 log cycle lower than the pasteurized skim control. Hoffmann et al. (1996), using an MF process with 1.4-μm membranes, reduced the total bacteria count of raw skim milk by 99.85%, with an average logarithmic reduction of 2.8. Elwell and Barbano (2006) found a 3.79 log reduction in total bacteria of raw skim milk was achieved by MF with 1.4-μm membranes, and a further 1.84-log reduction was achieved by following MF with HTST pasteurization (72°C for 15 s). These logarithmic reductions in bacteria counts may have the ability to lengthen the refrigerated shelf life of pasteurized milk. Schaffner et al. (2003), using Monte Carlo simulations, reported that reducing the average initial microbial contamination level of pasteurized milk by 0.5 log can significantly reduce the fraction of milk samples that spoil after 14 d of refrigerated shelf life when either mesophilic or psychotrophic microbes are present.

It is well known that if raw milk is left unmixed it will gravity separate or cream. This approach has been used commercially to prepare milk for the production of Grana Padano and Parmigiano-Reggiano cheeses (McSweeney et al., 2004). According to Rossi (1964), the number of total bacteria, coliform, thermophilic bacteria, and spores in partially skim milk is decreased to 5 to 10% of that in the starting raw whole milk when milk is gravity separated for 6 h at 15°C. Dellagio et al. (1969) showed that gravity separation of raw whole milk, to which a variety of pure bacterial cultures were added, caused *Clostridium tyrobutyricum* BZ15, *Streptococcus cremoris* 760 and 803, *Acinetobacter* 12-2 and R66, *Escherichia coli* NCDO 1246, *Pseudomonas flourescens* P442, and *Flavobacterium* 8-9 to rise to the top. Caplan et al. (2013) found that in raw and HTST pasteurized (72.6°C for 25 s) whole milk, the milk fat, bacteria, and somatic cells rose to the top of columns during gravity separation. About 50 to 80% of the milk fat and bacteria, and 90 to 96% of somatic cells were present in the top 8% of the milk weight in the column after gravity separation for 22 h of both milks. Therefore, gravity separation can also be used to physically remove bacteria from raw whole milk.

Elwell and Barbano (2006) reported that following MF with HTST pasteurization (72°C for 15 s) produced skim milk with extended shelf life (i.e., <20,000 cfu/mL) of up to 90 d at 2°C. The next step in research is to extend the shelf life of 2% fat milk to 60 to 90 d of refrigerated shelf life without using high heat. A combination of gravity separation to produce cream with low bacteria count, MF of skim milk, and HTST pasteurization might make this possible.