J. Dairy Sci. 100:1–14
https://doi.org/10.3168/jds.2016-11899


# The influence of ultra-pasteurization by indirect heating versus direct steam injection on skim and 2% fat milks

A. P. Lee,* D. M. Barbano,† and M. A. Drake*[1]
*Department of Food, Bioprocessing and Nutrition Sciences, Southeast Dairy Foods Research Center, North Carolina State University, Raleigh 27695
†Department of Food Science, Northeast Dairy Research Center, Cornell University, Ithaca, NY 14850

## ABSTRACT

Fluid milk is traditionally pasteurized by high temperature, short time (HTST) pasteurization, which requires heating to at least 72°C for 15 s. Ultra-pasteurization (UP) extends milk shelf life and is defined as heating to at least 138°C for 2 s. The UP process can be done by indirect heating (IND) or by direct steam injection (DSI). The influence of these 2 UP methods on milk flavor has not been widely investigated. The objective of this study was to compare the effect of HTST, IND-UP, and DSI-UP on sensory perception of fluid milk. Raw skim and standardized 2% milks were pasteurized at 140°C for 2.3 s by IND or DSI or by HTST (78°C, 15 s) and homogenized at 20.7 MPa. The processed milks were stored in light-shielded opaque high-density polyethylene containers at 4°C and examined by descriptive analysis and microbial analysis on d 3, 7, and 14. Furosine and serum protein denaturation analyses were performed on d 0 and 14 as an indicator of heat treatment. Lastly, consumer acceptance testing was conducted at d 10, with adults (n = 250) and children (ages 8 to13 y, n = 100) who were self-reported consumers of skim or 2% milk; consumers only received samples for either skim or 2% milk. The entire experiment was repeated in triplicate. Milks treated by HTST had lower cooked flavor than either UP milk. Milks heated by DSI-UP were characterized by sulfur or eggy and cooked flavors, whereas IND-UP milks had higher sweet aromatic and sweet taste compared with DSI-UP milk. Aromatic flavor intensities of all milks decreased across 14 d of storage. Furosine concentrations and serum protein denaturation were highest for the IND treatments, followed by DSI and HTST. Furosine content in both skim and 2% milk increased with time, but the increase was faster in IND-UP skim milk. Adult and child consumers preferred HTST milk over either UP milk, regardless of fat content. Ultra-pasteurization by IND or DSI did not affect consumer acceptance at 10 d postprocessing, but traditional HTST milks were preferred by consumers of all ages.
**Key words:** fluid milk, ultra-pasteurization, direct steam injection, flavor, consumer acceptance

## INTRODUCTION

Extended shelf life milks are a current industry trend to meet supply chain demands in the United States. With per capita fluid milk consumption declining 35% over the past 40 yr (USDA ERS, 2015), the implementation of nonconventional processing methods for milk are desirable to compete in the beverage industry. Typical US milks are processed by HTST pasteurization (minimum of 72°C for 15 s), resulting in shelf lives of 2 to 3 wk due to bacterial spoilage limitations (Boor, 2001). This is compared with soft drinks and juices, which can have 2 to 9 mo shelf life. Ultra-pasteurization (**UP**) is one method that can extend the shelf life of milk to periods comparable to soft drinks and juices. However, the extreme thermal treatment of this process can affect the sensory properties of milk, resulting in changes to consumer perception and acceptance of the milk compared with typical HTST milks. Ultra-pasteurization is defined by 21 CFR 131.3 (FDA, 2015) as thermal processing of milk "at or above 138°C (280°F) for at least two (2) seconds" to produce a product for extended shelf life under refrigeration. The thermal treatment of the UP process destroys not only pathogenic bacteria, but also spoilage microorganisms that are not completely destroyed during conventional HTST pasteurization.

Direct heating systems for UP treatment use superheated steam that is applied directly to the product, either by injecting the steam in-line into the product (direct steam injection) or by allowing product to pass through a steam-filled chamber (steam infusion; Bylund, 2003). The addition of steam to products adds

Received August 21, 2016.
Accepted October 31, 2016.
[1]Corresponding author: mdrake@ncsu.edu

water to the product and necessitates the removal of water by vacuum, which also acts to instantaneously cool the product (Datta et al., 2002). Mehta (1980) also previously reported that the cooked flavor of direct heat-treated milks was reduced due to removal of sulfhydryl groups by vacuum cooling. Direct methods also have advantages over indirect heating by tubular or plate heat exchangers in that the direct contact with the heating medium followed by instant cooling by vacuum allows for more efficient heat transfer. This produces smaller areas under the curve in the time-temperature profile of the treated product, limiting product quality loss from excess heat exposure (Datta et al., 2002; Bylund, 2003). Direct heat transfer by steam also greatly limits burn-on and fouling, as no heat transfer surfaces are present for the final heating step (Jelen, 1982).

Heat treatment, both time and temperature, affects milk sensory properties. Previous studies have noted several sensory differences in milks treated by UP methods, including cooked flavor and aroma, caramelized flavor, sweet, bitter, astringency, and color differences. The sulfurous, eggy flavor in some heated milk has been attributed to sulfhydryl compounds released from whey proteins, specifically β-LG, and proteins in the milk fat globule membrane due to thermal treatment (Mehta, 1980; Calvo and de la Hoz, 1992). Caramelized and other "brown" flavors are attributed to nonenzymatic browning reactions, such as from protein or sugar breakdown or by Maillard reaction (Shipe et al., 1978; Calvo and de la Hoz, 1992). These flavors typically decrease over time (Deane et al., 1967; Shipe et al., 1978); however, flavor differences are still present in milks even after several weeks of storage (Chapman and Boor, 2001; Grabowski et al., 2013). These flavor differences contribute to consumer perception of the milks. Chapman and Boor (2001) reported that children ages 6 to 11 yr old preferred HTST milk 1 d postprocessing over UHT milk at 24 to 30 d postprocessing, which were both liked more than UP milk at 6 to 7 d postprocessing. Gandy et al. (2008) reported consumer preference for HTST milks pasteurized at 79°C at 6 d postprocessing compared with milks pasteurized at 77°, 82°, and 85°C. Consumer clusters were distinguished by liking or disliking of cooked flavor (Gandy et al., 2008). In previous studies, descriptive analysis was not conducted. Studies have not compared consumer perception of UP milks to HTST milks in the past 10 yr, despite increased prevalence of UP milks in the marketplace and, presumably, increased consumer exposure to UP milk. Furthermore, and importantly, no published research has directly addressed the sensory properties of UP milks processed by indirect (**IND**) or direct steam injection (**DSI**); DSI UP is a more recent technology and is replacing, at least in part, many IND systems due to increased heat transfer efficiency.

Our study was designed to compare the sensory effects of these 2 UP techniques to each other and to traditional HTST milk. The objective of the current study was to understand the effect of heat treatment, UP with either DSI or IND and HTST, on sensory properties and consumer acceptance of skim and 2% fat milks.

## MATERIALS AND METHODS

### *Sample Preparation*

Prior to the study, preliminary processing runs were done for each of the 3 thermal processes that had different hardware configurations of the Microthermics milk processing system (Microthermics, Raleigh, NC). The milk going into the processing system and exiting the processing system were tested for fat, protein, and lactose by mid-infrared milk analysis, for freezing point using a milk cryoscope (model 4250, Advanced Instruments Inc., Norwood, MA), and for particle size using a laser light-scattering particle size analyzer. The purpose of the preliminary runs was to determine the volume of product that needed to be processed in each configuration to completely flush out water from the system and to determine if the homogenizer was performing properly. In the case of DSI, the cryoscope measures were also used to determine if the water added by steam injection was removed. The total volume of product need to flush water out of the Microthermics processing system was 10, 12, and 12 L for HTST, IND-UP, and DSI-UP, respectively.

For this study, 200 L of raw skim milk (3.1% protein, 0.07% fat) and raw cream (45.4% fat) were obtained from the North Carolina State University dairy facility. The cream was separated from raw whole milk by a cold bowl separator (Model 590, Separators Inc., Indianapolis, IN). One hundred liters of the raw skim milk was standardized to 2% fat milk with the raw cream. A Microthermics EHVH pasteurization unit running T12B software (10.11.12.90, v6.0, build 104) with a 2-stage homogenizer (model NS2006H, GEA Niro Soavi, Parma, Italy) was used to process the milks. For the HTST treatment, raw skim and raw 2% milk were processed at a flow rate of 2.0 L/min. Backpressure between the inlet pump and the homogenizer was maintained at 420 kPa. Following preheating to 60°C, the milks were homogenized and pasteurized at 78°C for 15 s before cooling to 10°C (Figure 1a). The IND-UP milks were processed at 1.3 L/min flow rate with the same backpressure applied to the homogenizer as with