J. Dairy Sci. 97:659–671
http://dx.doi.org/10.3168/jds.2013-7245

Effect of moderate inlet temperatures in ultra-high-pressure homogenization treatments on physicochemical and sensory characteristics of milk

G. G. Amador-Espejo,*† A. Suàrez-Berencia,* B. Juan,* M. E. Bárcenas,† and A. J. Trujillo*[1]
*Centre Especial de Recerca Planta de Tecnologia dels Aliments (CERPTA), XaRTA, TECNIO, MALTA Consolider, Departament de Ciència Animal i dels Aliments, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain
†Departamento de Ingeniería Química, Alimentos y Ambiental, Universidad de las Américas Puebla, Sta. Catarina Mártir, Cholula, Puebla, C.P. 72810, México

ABSTRACT

The effect of ultra-high-pressure homogenization (UHPH) on raw whole milk (3.5% fat) was evaluated to obtain processing conditions for the sterilization of milk. Ultra-high-pressure homogenization treatments of 200 and 300 MPa at inlet temperatures (Ti) of 55, 65, 75, and 85°C were compared with a UHT treatment (138°C for 4 s) in terms of microbial inactivation, particle size and microstructure, viscosity, color, buffering capacity, ethanol stability, propensity to proteolysis, and sensory evaluation. The UHPH-treated milks presented a high level of microbial reduction, under the detection limit, for treatments at 300 MPa with Ti of 55, 65, 75, and 85°C, and at 200 MPa with Ti = 85°C, and few survivors in milks treated at 200 MPa with Ti of 55, 65, and 75°C. Furthermore, UHPH treatments performed at 300 MPa with Ti = 75 and 85°C produced sterile milk after sample incubation (30 and 45°C), obtaining similar or better characteristics than UHT milk in color, particle size, viscosity, buffer capacity, ethanol stability, propensity to protein hydrolysis, and lower scores in sensory evaluation for cooked flavor.
Key words: ultra-high-pressure homogenization, milk sterilization, UHT milk

INTRODUCTION

Since its development, heat treatment has been by far the most applied technology to enhance milk shelf life, as it destroys pathogen microorganisms and most of the spoilage bacteria (Walstra et al., 2006). The cooked off-flavor, a result of the whey protein denaturation process caused by the temperature increase, is the greatest disadvantage of these treatments, along with the loss of some physicochemical and nutritional quality (Fox and McSweeney, 1998; Datta and Deeth, 2003; Walstra et al., 2006). From studies on the various heat treatments applied to milk, UHT treatment may increase shelf life to up to 6 or even 8 mo, with the main problems associated with the treatment being cooked off-flavor development, protein gelation, and nutritional compound destruction (Datta and Deeth, 2003; Cattaneo et al., 2008; Chavan et al., 2011).

For these reasons, the food industry is developing new processes to treat milk, with the intention of reducing the use of heat, using what are known as nonthermal technologies. Within the nonthermal technologies, several applications of ultra-high-pressure homogenization (**UHPH**; 100–400 MPa), which has previously been used in the pharmaceutical, chemical, and biochemical industries (Popper and Knorr, 1990; Floury et al., 2000), have already been studied by the food industry, with interesting results. The process is similar to the conventional homogenization used in the dairy industry, with improvements in both the valve material, which helps to reach pressures up to 400 MPa, and the geometry of the valve (Floury et al., 2004; Diels and Michiels, 2006; Huppertz, 2011). The most important processing parameters are the operating pressure, inlet temperature ($\mathbf{T_i}$), and number of passes (Datta et al., 2005; Diels and Michiels, 2006; Donsì et al., 2009; Dumay et al., 2013).

The UHPH process applied to milk has shown interesting results, such as the achievement of finer emulsions due to particle size reduction (Hayes et al., 2005; Zamora et al., 2007; Donsì et al., 2009), bacterial load reduction (including the reduction of pathogenic microorganisms; Diels and Michiels, 2006; Briñez et al., 2007; Pereda et al., 2007; Donsì et al., 2009), enzyme inactivation (Hayes and Kelly, 2003b; Datta et al., 2005; Hayes et al., 2005; Pereda et al., 2007), structural changes in the milk proteins through partial disassociation, and changes in the coagulation properties of milk (Datta et al., 2005; Sandra and Dalgleish, 2007; Zamora et al., 2007; Grácia-Juliá et al., 2008; Roach and Harte, 2008).

The main mechanisms involved in microbial reduction by UHPH treatment are shear stress, high-speed collisions, impingement, and cavitation (Paquin, 1999; Diels and Michiels, 2006; Donsì et al., 2009; Dumay et

Received July 9, 2013.
Accepted November 1, 2013.
[1]Corresponding author: Toni.Trujillo@uab.es

al., 2013). Even though the UHPH technology can be considered a nonthermal technology, fluid temperature elevation does occur, but for a very small fraction of time, if an appropriate cooling system is applied after the valve. This elevation is due to a variety of phenomena, such as shear stress, turbulence, cavitation, and the transformation of kinetic energy into heat during the pressure increase (Datta et al., 2005; Diels and Michiels, 2006; Donsì et al., 2009). This temperature increase makes an important contribution to microbial reduction and other changes in milk characteristics.

Several authors have suggested the use of UHPH treatment to reach similar levels of microbial load reduction as heat pasteurization. In this regard, Hayes et al. (2005) applied UHPH treatments of 250 MPa at T_i = 45°C to milk, obtaining a microbial load decrease of 3 log cfu/mL. Furthermore, Pereda et al. (2006), applied UHPH treatments of 300 MPa at T_i = 30 and 40°C and achieved microbial reductions of around 4 log cfu/mL. Smiddy et al. (2007) carried out UHPH treatments of 200 and 250 MPa at T_i of 55 and 70°C, reaching microbial reductions of above 5 log cfu/mL. More recently, Ruiz-Espinosa et al. (2013) used UHPH treatments of 250 MPa at T_i = 25°C with 3 passes, obtaining microbial reductions above 5 log cfu/mL. Other authors have shown that UHPH is able to produce milk with a shelf life similar to heat-pasteurized milk. Similarly, Pereda et al. (2007) attained a shelf life longer than 15 d in UHPH milk treated at 300 MPa with a T_i of 30 and 40°C.

From these studies, it is important to notice the effect of inlet temperatures on microbial load reduction when it is combined with pressure treatments above 250 MPa. Nevertheless, at the moment, only a few studies have been published regarding the use of UHPH treatments with moderate inlet temperatures (between 50 and 90°C) to obtain milk of a high microbiological quality (i.e., sterile milk) while maintaining the sensory characteristics and reducing physicochemical changes. For these reasons, the aim of this study was to explore the possibility of obtaining sterile milk by applying UHPH treatments at moderate inlet temperatures; to evaluate microbial reduction, sensory, and physicochemical changes; and to compare the results to those obtained from UHT milk.

MATERIALS AND METHODS

Milk Supply

Fresh raw bovine milk (11.72 ± 0.45% TS and 3.37 ± 0.09% protein) was obtained from a local producer (Can Badó, La Roca del Vallès, Spain), standardized at 3.5 ± 0.06% fat, and then stored for 24 h at 4°C.

UHPH and UHT Milk Treatments

The UHPH treatment of milk tested in this study was performed in a Stansted high-pressure homogenizer (model FPG11300; Stansted Fluid Power Ltd., Harlow, UK). The equipment comprises a high-pressure ceramic valve able to support 350 MPa and a second pneumatic valve, located after the first, able to support up to 50 MPa. The high-pressure system consists of 2 intensifiers driven by a hydraulic pump. The flow rate of the milk in the homogenizer was approximately 120 L/h. To minimize temperature retention after treatment and its effect on milk properties, 2 spiral-type heat-exchangers were located behind the second valve, as described by Guamis et al. (2010). The T_i and the temperature both before the first homogenization valve (**T1**) and after the homogenization process (**T2**) were monitored throughout the experiment. In all experiments, the outlet temperature was approximately 15°C. Milk was UHPH treated under the following conditions: 200 and 300 MPa at the first valve with T_i of 55, 65, 75, and 85°C without using the second valve.

Before UHT treatment, a traditional milk homogenization process was carried out in a double-stage Niro Soavi homogenizer (model X68P; GEA Niro Soavi, Parma, Italy) at 18 + 4 MPa (first valve pressure + second valve pressure) at 65°C. A UHT milk treatment was then applied in a tubular indirect Finamat heat exchanger (model 6500/010; GEA Finnah GmbH, Ahaus, Germany) at 138°C for 4 s. Samples of both treatments were manually collected in sterile bottles (50 mL), in a laminar flow clean air bench cabinet (Mini V/PCR; Telstar, Terrassa, Spain), previously sterilized to obtain aseptic conditions.

Collected samples were immediately cold stored at 4°C, except for those incubated for sterility control. Three replicates of each experiment were conducted.

Compositional Analysis

Protein and fat content were determined by duplicate using the Dumas and Gerber methods, respectively (IDF, 1981, 2002). The TS and ashes analyses were carried out according to the International Dairy Federation (**IDF**, 1987) and AOAC International (2000; method 945.46) standards, respectively. The milk pH was evaluated at d 1 by electrode immersion with a micro pH-potenciometer (model 2001; Crison Instruments SA, Alella, Spain).

Microbiological Analysis

To determine the microbial load reduction obtained, before treatments the following microbial groups were