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Development and shelf-life determination of pasteurized, microfiltered, lactose hydrolyzed skim milk

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ABSTRACT

The segment of the world population showing permanent or temporary lactose intolerance is quite significant. Because milk is a widely consumed food with an high nutritional value, technological alternatives have been sought to overcome this dilemma. Microfiltration combined with pasteurization can not only extend the shelf life of milk but can also maintain the sensory, functional, and nutritional properties of the product. This studied developed a pasteurized, microfiltered, lactose hydrolyzed (delactosed) skim milk (PMLHSM). Hydrolysis was performed using β-galactosidase at a concentration of 0.4 mL/L and incubation for approximately 21 h at 10 ± 1°C. During these procedures, the degree of hydrolysis obtained (>90%) was accompanied by evaluation of freezing point depression, and the remaining quantity of lactose was confirmed by HPLC. Milk was processed using a microfiltration pilot unit equipped with uniform transmembrane pressure (UTP) ceramic membranes with a mean pore size of 1.4 μm and UTP of 60 kPa. The product was submitted to physicochemical, microbiological, and sensory evaluations, and its shelf life was estimated. Microfiltration reduced the aerobic mesophilic count by more than 4 log cycles. We were able to produce high-quality PMLHSM with a shelf life of 21 to 27 d when stored at 5 ± 1°C in terms of sensory analysis and proteolysis index and a shelf life of 50 d in regard to total aerobic mesophile count and titratable acidity.
Key words: lactose hydrolyzed milk, microfiltration, shelf life

INTRODUCTION

It has been estimated that at least 65% of the adult world population manifests signs and symptoms of lactose intolerance, and the prevalence of this inability to digest lactose varies considerably between different races and age ranges. The distribution of different lactase phenotypes in human populations is highly variable, an observation that has long been a source of interest in relation to evolutionary genetics. Family studies suggest that adults who are lactase nonpersistent (lactose intolerant) are homozygous for an autosomal recessive allele that causes the postweaning decline in lactase activity, whereas people who are lactase persistent (lactose tolerant) are either heterozygous or homozygous for a dominant allele that allows lactase to persist (Swallow, 2003).

The recommendation for individuals with hypolactasia or alactasia is the reduction or exclusion of lactose-containing foods from the diet (Rusynyk and Still, 2001). However, with the exclusion of dairy products from the diet, lactose-intolerant individuals generally show low ingestion of calcium and other nutrients provided by milk (Batista et al., 2008). One option in these cases is the consumption of lactose hydrolyzed products. The conversion of lactose to its constituent monosaccharides by hydrolysis has been practiced industrially for almost 20 yr and recent research has focused on the determination of residual lactose in delactosed milk by calculating its freezing point (Colinas et al., 2006). Lactose hydrolyzed milk is milk with a reduced lactose content (normally reduced by 90%), this reduction being obtained by the action of the enzyme β-galactosidase, which promotes enzymatic hydrolysis of the lactose. Although lactose-free milks have addressed the needs of lactose-intolerant consumers, such products need to have strong similarity to regular milk for the consumer to purchase and be satisfied with the products (Adhikari et al., 2010).

One significant barrier to extending the shelf life of dairy products is the difficulty in achieving the removal or destruction of spoilage microorganisms and spores present in raw milk while limiting product color changes, vitamin destruction, and milk protein denaturation (García and Rodríguez, 2014). The application

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of a combination of pasteurization and microfiltration to milk has the potential to yield high-quality milk with an extended shelf life (Schmidt et al., 2012) and it improves the keeping quality of cheese made from the milk due to removal of the spores (Pafylias et al., 1996). Microfiltration is the technology used to separate the components of a liquid medium, the separation occurring when the medium is forced to flow, under low pressure (~100 kPa), over the surface of a semipermeable membrane with pore sizes ranging from 0.2 to 5 μm (Dziezak, 1990; Fernández García et al., 2013). This technique can be used to reduce the microbial load of milk by mechanical separation, without causing heat-induced chemical alterations, thus conserving the sensory, functional, and nutritional properties of the milk (Hoffmann et al., 2006). Bacteria generally range from 0.4 to 2 μm in size; therefore, under certain circumstances, microfiltration should be able to completely remove bacteria from the fluid permeate (Fernández García et al., 2013). Madec et al (1992) observed decimal reductions in milk close to 1.9 units for *Listeria* and 2.5 units for *Salmonella* using a multichannel microfiltration membrane with a 1.4-μm pore size. In milk processing, a pore size of about 1.4 μm is normally used to achieve the right balance between rejection of bacteria and little or no rejection of milk nutrients (García and Rodríguez, 2014).

Pasteurized, microfiltered, lactose hydrolyzed skim milk (of which the microbiological, physicochemical, and sensory characteristics are presented in this paper) is an innovative product, and scientific literature on this type of product is scarce. However, milk processed using microfiltration (**MF**) and HTST (72°C for 15s) pasteurization (without lactose hydrolysis) is commercially available in Canada and northern European countries, it has a mean shelf life of 35 d at 6°C (Saboya and Maubois, 2000; Elwell and Barbano, 2006; Mintel, 2013).

Thus, the objectives of the present work were to (1) develop a pasteurized, microfiltered, lactose hydrolyzed skim milk, (2) evaluate its physicochemical, microbiological and sensory characteristics, and (3) estimate its shelf life.

MATERIALS AND METHODS

Milk Samples and Enzyme

About 240 L of skim milk produced on only one farm was pasteurized at 72 to 75°C for 15 to 20 s and bottled on the farm premises according to Brasil (2011). β-Galactosidase (EC 3.2.1.23) isolated from *Kluyveromyces lactis* (50,000 U/mL) was donated by Prozyn SP/Brazil (Sao Paulo, Brazil).

Product Processing and Storage

Two batches of the pasteurized, microfiltered, lactose hydrolyzed skim milk (**PMLHSM**) were produced, each using 120 L of milk. The final products were stored for 60 d at 5 ± 1°C and evaluated for their microbiological, physicochemical, and sensory parameters every 7 d.

Hydrolysis of Milk Lactose

For each processing, β-galactosidase was initially added to the pasteurized milk at a concentration of 0.4 mL/L, and incubated for about 21 h at 10 ± 1°C (lactose hydrolysis condition selected in preliminary tests). During these procedures, the degree of hydrolysis obtained (above 90%) was accompanied by measurement of freezing point depression, according to Ramet et al. (1979) and the remaining quantity of lactose was confirmed by HPLC according to the methodology proposed by Burgner and Feinberg (1992). The detection limit of the HPLC method was 0.2 g of lactose per 100 mL of milk.

Microfiltration of the Milk

After hydrolysis of the lactose, the milk was submitted to MF in a microfiltration MFS-1 pilot unit (Tetra Laval, Paris, France), equipped with uniform transmembrane pressure (**UTP**) ceramic membranes (Membralox, Societe des Céramiques, Bazet, France). The MFS-1 unit was equipped with a 1P19-40 filter module containing a ceramic element with 0.24-m^2 membrane area, which allows a capacity of approximately 150 L of skim milk/h, and with a mean pore size of 1.4 μm. The parameters of the process were as follows: permeate flux of 120 L/h, retentate flux of 6.3 L/h, volumetric concentration factor (VCF) of 20, and temperature of 48 ± 1°C. To minimize membrane fouling, a UTP of 60 kPa was used. Sterile 1-L glass bottles were filled with the MF milk using an automatic doser inside a laminar flow chamber.

Microbiological Analyses of the Milk After MF and During Storage

Before and immediately after MF, counts were made of total mesophilic aerobes, total psychrotrophic aerobes, coliforms at 30°C and 45°C, coagulase-positive staphylococci, *Salmonella* spp., and yeasts and molds. The following microbiological analyses were carried out every 7 d: total mesophilic count, coliforms at 30°C, coliforms at 45°C, and yeasts and molds.