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Influence of multilayer packaging and microfiltration process on milk shelf life

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ABSTRACT

As shelf life of pasteurized milk is relatively short the application of microfiltration was investigated as a way to increase milk shelf life. Raw milk was microfiltered and stored in bottles or pasteurized and stored in packages made from one of three different low density polyethylene (LDPE) multilayer films or a LDPE monolayer film. The results proved the efficiency of the 0.8 μm-microfiltration process in increasing shelf life of milk to at least 30 d with a reduction of the total microorganism count to a range of 5 $\log_{10}$. Specific properties of the various films led to different results concerning the barrier of the packages; however these differences did not have great influence on the shelf life of pasteurized milk. Evaluated packaging materials proved to provide sufficient protection to pasteurized milk and allow it to maintain its quality; therefore, the least expensive film may be chosen for use in commercial application.

1. Introduction

Milk is the secretion of mammary glands of more than 4500 female mammal species, whose natural function is to provide nutrition for the young. Milk is considered a complete food that contains fat, proteins, carbohydrates, minerals, vitamins, enzymes and approximately 100,000 different chemical compounds in various states of dispersion (Walstra, Wouters, & Geurts, 2006, chap. 1). Cow's milk is present in most Brazilian homes, with a consumption of 161 L per capita registered in 2010 (CNA, 2010). This level of consumption is equivalent to 74% of the three daily servings per day, or 220 L/year, that the World Health Organization/Food and Agriculture Organization (FDA, 2010) recommends. In the first quarter of 2013, the price of raw milk (for the producer), in Brazil was, on average, $0.49 per liter and the final milk product was sold at a price of $0.74 and $1.05 per liter for pasteurized and ultra high temperature (UHT) treated milk, respectively (CEPEA, 2013). Milk has a significant social–economic and cultural importance in Brazil. In 2010, Brazil produced more than 30 billion liters of milk, reaching approximately $12 million (CNA, 2010) and making the dairy chain an important source of jobs and profitability. Given the nutritional and social–economic importance of this product, the added value due to the package, for example should not cause a big inflation of the prices for the consumers.

With an increase in industrialization, even people living far away from the production sites have easy access to milk and its products. However, in order to preserve the product during transportation and storage, the use of preservation techniques such as heat treatment is necessary. In Brazil, for example,

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pasteurization is normally used to ensure food safety, nevertheless the resulting shelf life ranges only from 3 to 8 d. This short shelf life is linked to the poor bacteriological quality of the raw material, inappropriate storage temperatures and inefficient packaging systems.

Heat treatment can damage the biological properties of milk components, impair protein availability, and promote intolerance and allergy. The rise of alternative technologies, such as microfiltration, can help prevent these problems while also assuring food safety. Microfiltration is defined as a pressure-driven membrane separation process that utilizes porous membranes with average pore size diameter above 0.1 μm allows for the retention of all milk particles, including bacteria, somatic cells and spores. This technique can lead to a decimal reduction of bacteria above 3.5 (Carvalho & Maubois, 2010) and improve the microbiological safety in dairy products. Saboya and Maubois (2000) showed that milk treated by microfiltration with a 1.4 μm pore diameter can be considered as safe as pasteurized milk. Recently, 0.8 μm membranes have been applied instead of 1.4 μm membranes for the production of extended shelf life MF pasteurized milk (Carvalho & Maubois, 2010).

After eliminating contamination, it is also important to preserve milk quality during storage. The type of milk packaging may affect milk's quality characteristics by controlling directly the amount of oxygen and light in contact with the milk or by providing a perfect isolation in order to avoid post-contamination by microorganisms (Vassila, Badeka, Kondyli, Savvaidis, & Kontominas, 2002).

This work was performed with the following aims: (i) evaluate the effect of different barrier packages in maintaining the microbiological and nutritional quality of the milk, and (ii) evaluate the effectiveness of the 0.8 μm-microfiltration technique in raw milk, with focus on physicochemical and microbiological characteristics. With these proposals, we would like to show how multilayer packages and microfiltration processes can affect milk shelf life and to propose viable alternatives to improve milk processing, marketing and distribution, especially in less developed countries.

2. Materials and methods

2.1. Packaging material

The following low density polyethylene (LDPE) films were used in the experiments: (A) multilayer film pigmented with a black color on the inside and a white color on the outside (SCLAIRFILM-80E0337W7, Dupont™); (B) multilayer film pigmented with a white color on both sides (SCLAIRFILM-90B0324PW, Dupont™); (C) multilayer film pigmented with a black color on the inside and a white color on the outside (SCLAIRFILM-90E0323W7, Dupont™), produced by Dupont™ Pouch and (D) monolayer film pigmented with white TiO_2, which is commonly used to package pasteurized milk in Brazil.

2.2. Packaging analysis

The multilayer films were analyzed for oxygen transmission rate, light transmission, elasticity and tension strength. In addition, the thickness of each layer and roughness of the food contact surface were evaluated.

2.2.1. Oxygen transmission rate

The oxygen transmission rate (OTR) was determined according to ASTM D 3895-02. The OTR was measured four times by a headspace gas analyser (Model 6600 Headspace Oxygen/Carbon Dioxide Analyzer, Illinois Instruments, Johnsburg, IL, USA).

2.2.2. Light transmission

The characteristics of the transmission spectra (250–780 nm) (Moyssiadi et al., 2004; Rysstad, Ebbesey, & Eggestad, 1998; van Aardt, Duncan, Marcy, Long, & Hackey, 2001; Zygoura et al., 2004) for all packaging samples were analyzed using a UV–Vis spectrometer (Model 1601, Shimadzu, Kyoto, Japan).

2.2.3. Elasticity and tension strength

The films (30 mm $\times$ 20 mm) were analyzed for elasticity and tension strength according to ASTM D 882-02 using an Instron Universal Testing Machine (Model 3367, Instron®, Norwood, MA, USA) with a 1 kN load cell, speed of approximately 8.3 mm s^{-1} and initial distance of 35 mm between grips. The experiments were repeated eight times.

2.2.4. Microscopic characteristics

The microscopic characteristics of the films were evaluated by scanning electron microscopy (SEM) and atomic force microscopy (AFM). In the SEM analysis, pieces of films (20 mm $\times$ 50 mm) from each treatment were cut and fixed in a support (stub). The samples were covered with 20 nm of gold inside a Balzers metalizer (Model FDU 010, Bal-Tec, Balzers, Liechtenstein) and were observed and photographed with a LEO scanning electron microscope (Model 1430 VP, Carl Zeiss, Cambridge, England) (Pires et al., 2008).

The AFM was carried out using a microscope (Model NTEGRA PRIMA, MDT, Moscow, Russia) in an intermittent contact mode. The samples were analyzed in air at room temperature. The roughness measurements were performed with a scanning range of 10 μm $\times$ 10 μm. Measurements were made in three randomly chosen areas in all samples (Camilloto et al., 2010).

2.3. Preparation of milk samples

Milk obtained by good manufacturing practices was used. The milk was standardized to 3.0% fat in a centrifuge (Model RT50T, REDA Food Processing Plants, Vicentina, Italy), pasteurized at 74 °C for 15 s in a plate heat exchanger (Model Eurocal 18 CFG, Fish Term, São Paulo, Brazil) and cooled to 4 °C. The milk was immediately packaged in 1000 mL volumes with each packaging type and the appropriate equipment (Model El2000, Emil, Além Paraíba, Brazil). Packaged milk was stored at 5 °C in the presence of light using a display cabinet placed in a room with fluorescent light for 21 d.

2.4. Microfiltration

Skimmed milk, previously heated to 50 °C in a double jacketed tank was subjected to a MF module (Model MFS-1, Tetra Pak