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Comparison of Sensory, Microbiological, and Biochemical Parameters of Microwave Versus Indirect UHT Fluid Skim Milk During Storage

D. A. Clare, W. S. Bang, G. Cartwright, M. A. Drake, P. Coronel, and J. Simunovic
Southeast Dairy Foods Research Center, Department of Food Science,
North Carolina State University, Raleigh 27695-7624

ABSTRACT

Shelf-stable milk could benefit from sensory quality improvement. Current methods of heating cause flavor and nutrient degradation through exposure to overheated thermal exchange surfaces. Rapid heating with microwaves followed by sudden cooling could reduce or eliminate this problem. The objectives for this study were focused on designing and implementing continuous microwave thermal processing of skim fluid milks (white and chocolate) to compare sensory, microbiological, and biochemical parameters with conventionally prepared, indirect UHT milks. All test products were aseptically packaged and stored at ambient temperature for 12 mo. Every 3 mo, samples were taken for microbiological testing, reactive sulfhydryl determinations, active enzyme analysis, instrumental viscosity readings, color measurements, and descriptive sensory evaluation. Microbiological plate counts were negative on all milks at each time point. Enzymatic assays showed that plasmin was inactivated by both heat treatments. 5,5′-Dithio-bis(2-nitrobenzoic acid) analysis, a measure of reactive sulfhydryl (-SH-) groups, showed that the initial thiol content was not significantly different between the microwave-processed and UHT-treated milks. However, both heating methods resulted in an increased thiol level compared with conventionally pasteurized milk samples due to the higher temperatures attained. Sulfhydryl oxidase, a milk enzyme that catalyzes disulfide bond formation using a variety of protein substrates, retained activity following microwave processing, and decreased during storage. Viscosity values were essentially equivalent in microwave- and UHT-heated white skim milks. Sensory analyses established that UHT-treated milks were visibly darker, and exhibited higher caramelized and stale/fatty flavors with increased astringency compared with the microwave samples. Sweet aromatic flavor and sweet taste decreased during storage in both UHT and microwave milk products, whereas stale/fatty flavors increased over time. Sensory effects were more apparent in white milks than in chocolate varieties. These studies suggest that microwave technology may provide a useful alternative processing method for delivery of aseptic milk products that retain a long shelf life.
(**Key words:** ultra-high temperature, microwave, sulfhydryl oxidase, sensory)

Abbreviation key: DTNB = 5, 5′-dithio-bis(2-nitrobenzoic acid), **SHOX** = sulfhydryl oxidase.

INTRODUCTION

Thermal treatment of milk products has a significant impact on the dairy industry. These processing regimens (a) minimize bacterial growth, providing safer foods, (b) alter shelf life, and (c) affect parameters related to product functionality. Often, heat treatment causes milkfat globule membrane proteins and whey proteins to unfold such that buried sulfhydryl (-SH-) groups, normally masked in the native protein, are exposed to the outer surfaces (Hoffmann and van Mill, 1997). In turn, these processes produce extreme cooked flavors, often attributed to changes in the sulfhydryl and disulfide content of the protein fraction (Swaisgood et al., 1987).

Conventional pasteurization methods have long been in place and with the advent of UHT technology, the sterilization of fluid milk was achieved using higher temperature treatments for shorter periods. However, shelf-stable milk has met with limited acceptability by the consumer, especially in the United States, due in part to a high cooked flavor. Several attempts to improve the quality of UHT-treated milk products proved successful to varying degrees. Previously, Swaisgood and coworkers used immobilized sulfhydryl oxidase to reduce the thiol content of UHT-heated skim milk and described an improved flavor after enzymatic oxidation to form protein disulfide bonds (Swaisgood et al., 1987). Other studies have showed that altering UHT processing parameters, such as indirect vs. direct steam injection systems, cooling rates, and long-term storage conditions have a significant impact on sensory attri-

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Corresponding author: M. A. Drake; e-mail: mdrake@unity.ncsu.edu.

butes (Browning et al., 2001). Most recently, epicatechin, a flavonoid compound, was added to UHT milk prior to heating, and the results revealed partial inhibition of thermally generated cooked aroma (Colahan-Sederstrom and Peterson, 2005).

Alternative technologies, such as microwave processing, have also evolved. Microwaves, an element of the electromagnetic spectrum, range in frequency between 300 MHz and 3 GHz, and their routine application in heating foods is already prevalent, especially in developed countries. Since the early 1960s, microwave energy has been used for cooking, baking, and thawing. Hamid et al. (1969) were the first group to use the technology for milk pasteurization. Unlike other energy delivery systems, microwave heating involves a rapid and direct heating process that reduces the time required to achieve a desired temperature. Hence, the total cumulative thermal treatment is much reduced, better preserving the thermolabile constituents of foods, such as aromas, vitamins, and pigments (Mudgett, 1986) while maintaining the sterility of the final product by minimizing bacterial growth (Merin and Rosenthal, 1984).

Based on our review of the literature, there are relatively few reports that describe the effects of microwave processing on sensory, microbiological, rheological, and biochemical parameters of heated milk during long-term storage. In fact, we found only one article that discussed chemical and sensorial changes that occurred during cold storage of microwave-treated milk over a 15-d period (Valero et al., 2001). Therefore, our study was designed to evaluate the effects of microwave vs. indirect UHT heating regimens on these attributes using fluid skim milk products, both white and chocolate varieties, stored at room temperature (21°C) over a much longer period (12 mo). Specifically, the objectives were focused on determining the differences between these processes in 1) bacterial counts, 2) plasmin activity, 3) DTNB reactive protein sulfhydryl groups, 4) sulfhydryl oxidase activity, 5) viscosity, 6) color parameters, and 7) descriptive sensory attributes. These results suggested that microwave processing regimens might deliver an equivalent quality fluid milk product that retains a long-term, stable, shelf life.

MATERIALS AND METHODS

Preparation of Milk

Raw milk (1000 kg, 3.2 ± 0.2% protein, 3.8 ± 0.2% fat) was collected from the North Carolina State University dairy facility on 2 occasions. Raw skim milk (0.35 ± 0.01% fat) was obtained by centrifugal separation and used in subsequent studies. On each occasion, skim milk was evenly divided (500 kg) and assigned to the respective flavor content (white or chocolate). Chocolate milk was prepared by adding UHT SIPT 8, a UHT chocolate milk formulation comprising cocoa processed with alkali, starch, salt, carrageenan, vanillin, and other artificial flavorings (Benjamin P. Forbes Company, Cleveland, OH). This ingredient was added at the ratio of 1.2 g of cocoa powder mix/100 g of milk in conjunction with cane sugar (7.6 g of sugar/100 g of milk). White and chocolate milks, 250 kg each, were then separated for UHT vs. microwave sterilization. High temperature, short time milk, or pasteurized milk, was prepared at a high temperature for a short time (at least 71.7°C for 15 s or an equivalent combination).

UHT Processing Methodology

Skim milk was subsequently heated using a traditional UHT processing unit that delivers thermal energy via an indirect steam injection system (No-Bac Unitherm model VIII Cherry Burrell, Corp., Louisville, KY). In this paper, the abbreviation UHT is specifically defined as indirect UHT milk, based on this particular method of preparation (indirect steam injection). White milk was heat-treated at 137.8°C for 10 s fastest particle (heating rate: 3.26°C/s, 20-s average hold time, Fo = 8), whereas chocolate milk was thermally processed at 140.6°C for 10 s fastest particle (heating rate: 3.33°C/s, 20-s average hold time, Fo = 15). Fo is a process temperature equivalent unit, whereby an Fo = 1 indicates that a product received a heat treatment equivalent to 121°C for 1 min. The flow rate was approximately 2.0 L/min. It is important to note that with steam heating, there is a gradation of thermal energy because heat is delivered from the outside area of the processing chamber to the interior (indirect heating). As a result, the outermost surfaces of the milk product were likely superheated.

Microwave Processing Methodology

For microwave processing, a 60-kW continuous flow microwave-heating unit (IMS 60 kW microwave system, Industrial Microwave Systems, Morrisville, NC), operating at 915 MHz, was used to process skim milks. Microwaves were focused to a cylindrical applicator, and the power relayed from the generator was monitored using a control panel supplied by the manufacturer. Microwaves were then delivered to the product by a waveguide of rectangular cross-section, which was split into 2 sections and geared towards 2 specially designed applicators, with a directional coupler in each. A polytetrafluoroethylene tube (0.038 m i.d.) was placed at the center of each applicator and the exposure region was 0.2 m long in each applicator (Coronel et al., 2003).