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Sugar reduction of skim chocolate milk and viability of alternative sweetening through lactose hydrolysis

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ABSTRACT

Milk consumption by Americans has not met the standards of the Dietary Guidelines for Americans. Chocolate milk can improve milk consumption, especially by children, due to its color and taste. However, the high sugar content of chocolate milk is a cause for concern about its healthfulness, resulting in its removal from some school lunch programs. It is important to reduce the sugar content of chocolate milk and still maintain acceptability among consumers. It is also important to investigate other natural alternatives to sweetening. The objectives of this study were to identify the different sweetness intensity perceptions of sucrose in water and various dairy matrices, to identify the acceptable reduction in sweet taste for chocolate milk for both young adults (19–35 yr) and children (5–13 yr), and to determine if lactose hydrolysis is a viable alternative. Threshold and power function studies were used to determine the benchmark concentration of sucrose in chocolate milk. The acceptability of sugar reduction from the benchmark concentration for both young adults and children and the acceptability of lactose hydrolyzed chocolate milk (4°C for 24 h) with added lactose for young adults were evaluated. Acceptability results demonstrated that sugar reduction in chocolate milk is possible for both young adults and children as long as it does not exceed a 30% reduction (from 205 m*M*). Lactose hydrolysis of added lactose was used to achieve the sweetness of sucrose in chocolate milk but required >7.5% (wt/vol) added lactose, which contributed undesirable calories, indicating that lactose hydrolysis may be more suitable for other dairy beverages that require less added sugar. The findings of this study demonstrate consumer acceptance of reduced-sugar chocolate milk and a possible way to use lactose hydrolysis in dairy beverages.

Key words: chocolate milk, power function, sugar reduction, lactose hydrolysis

INTRODUCTION

The Dietary Guidelines for Americans recommend that adult Americans consume 3 cups (710 mL) per day of fat-free or low-fat milk or equivalent milk products (USDA-HHS, 2010). Studies have shown that flavored milk increases milk consumption among both adults and children (Anonymous, 2003; Murphy et al., 2008). Flavored milk provides essential nutrients similar to that of plain milk and other milk products (Murphy et al., 2008) and, because of its pleasurable taste, has gained popularity among children and adults (Kim et al., 2013). In 2011, sales in flavored milk and milk drinks reached $731 million in the United States (International Dairy Foods Association, 2012). Chocolate is the most popular milk flavor for both children and adults (Boor, 2001; Thompson et al., 2004, 2007; NDC, 2010). Various studies have addressed the relationship between high sugar consumption and health concerns such as obesity (Berkey et al., 2004; Malik et al., 2006); therefore, despite the popularity of chocolate milk and the benefit of increasing milk consumption for children and adults, the high sugar content of chocolate milk has raised health concerns. The Los Angeles school system recently banned flavored milk as part of a child obesity prevention program (Hoag, 2011). However, Quann and Adams (2013) determined that eliminating flavored milk in elementary schools decreased overall milk consumption and, to replace the nutrient deficit from the milk consumption, additional foods with more fat and calories would be required. Therefore, the balance between increasing milk consumption while maintaining low sugar content is important.

Sugar reduction is usually achieved by replacing sugar with nonnutritive sweeteners. However, the disadvantages of these sweeteners are that they are often artificial, which are not label friendly, and often carry metallic or bitter taste and aftertastes (Schiffman et al., 1995). The naturally existing milk sugar lactose has

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a lower relative sweetness compared with its monosaccharide constituents glucose and galactose. Lactase is currently used by the dairy industry to produce lactose-free milk. As such, lactose hydrolysis of milk with added dried dairy ingredients such as lactose or whey permeate might be a label-friendly method to sweeten chocolate milk naturally. Lactose hydrolysis is usually conducted before pasteurization of raw milk or after pasteurization followed by heat treatment to deactivate the enzyme. Sterile lactase can also be added into UHT milk with aseptic packaging, where the lactose will be hydrolyzed during the first few days of storage. If an acceptable sweetness of chocolate milk could be achieved by hydrolyzing added lactose or a high-lactose dairy ingredient such as whey permeate, it would provide an alternative way of sweetening chocolate milk. To our knowledge, no published work has addressed this question.

Various studies have been conducted on the effect of sugar reduction on sensory perception of different foods and beverages but to our knowledge, no studies have described the dose–response relationship of sucrose in different dairy matrices, especially chocolate milk. It is important to understand sweetness perception of chocolate milk and what level of sugar reduction can be achieved without affecting consumer acceptance. The objectives of this study were to identify the sweetness intensity perception of sucrose in water and various dairy matrices, to identify the acceptable sweet taste reduction for chocolate milk for both young adults and children, and to determine if lactose hydrolysis is a viable alternative to sweeten chocolate milk.

MATERIALS AND METHODS

Experimental Overview

Two experiments (experiments 1 and 2) were conducted to achieve the objectives of this study. In experiment 1, the acceptable sugar reduction of skim chocolate milk for both young adults and children was identified. Threshold and power function studies were conducted to determine a representative concentration of sucrose in skim chocolate milk comparable to commercial product. Based on the benchmark concentration, different percentages of sucrose reduction in chocolate milk were evaluated by both young adults and children. In experiment 2, the objective was to determine if lactose hydrolysis was a viable alternative to sweeten skim chocolate milk. The lowest acceptable sweet level from experiment 1 for both young adults and children was chosen as the sweet taste target for lactose hydrolysis experiments. The acceptance of chocolate milk sweetened by lactose hydrolysis compared with sucrose-sweetened chocolate milk was then evaluated by young adults.

Chocolate Milk Manufacture

Chocolate milk base without added sugar used for bench-top studies for power function and lactose hydrolysis studies was manufactured by adding 10.19 g of cocoa powder (NC85, Benjamin P. Forbes Company, Broadview Heights, OH) to 1 L of raw skim milk. The mixture was pasteurized at 69°C for 30 min, and then immediately fed to a 2-stage homogenizer (Panda 2K, Niro Inc., Columbia, MD) at 2,000 kPa (first stage) and 4,000 kPa (second stage). The milk was cooled and stored at 4°C. Sucrose was then added at different concentrations in each experiment. Chocolate milk for consumer tests was manufactured by the North Carolina State University (**NCSU**) Dairy Education Unit (Raleigh, NC) using skim milk and the same cocoa powder concentrations (described in the Consumer Acceptance sections).

Experiment 1: Sugar Reduction in Skim Chocolate Milk

Threshold Determination. All sensory testing protocols were approved by the NCSU Institutional Review Board. The detection and recognition threshold of sucrose in water, skim milk, whole milk, and skim chocolate milk was determined using a 7-series ascending 3-alternative forced choice method (ASTM International, 1991; Plotto et al., 2004; Drake et al., 2011). Samples (30 mL) were presented in lidded 60-mL soufflé cups with 3-digit codes, and the series was presented in ascending concentration. The sweetness levels were presented with a dilution factor of 3 (0.111 to 81 mM sucrose in water, 0.333 to 243 mM sucrose in milks). In each series, samples were randomized. All samples were equilibrated to 20°C before testing.

Subjects (n = 40) were instructed how to evaluate the samples before testing, and the sure/not sure modification detailed by Lawless et al. (2000) was used. Subjects were asked to remove the cup lid and taste each sample, and then to choose the 1 item of the 3 that they thought was different. Subjects were also asked if they recognized the difference. Subjects were asked to give certainty judgments (sure/not sure) for both difference and recognition. The individual best-estimated threshold was determined by calculating the geometric mean of the last concentration with an incorrect response and the first concentration with a correct response, with all subsequent responses correct. If the subject indicated a "not sure" response for the correct choice, a factor of 1.41 was multiplied to adjust for the