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Sweetness potency and sweetness synergism of sweeteners in milk and coffee systems

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ABSTRACT

This study investigated the presence of sweetness synergism in milk and instant coffee systems. It consists of three parts: 1) modeling concentration–sweetness intensity curves of sweeteners (stevia, sucralose, xylose, tagatose and erythritol); 2) measuring the sweetness potencies of sweeteners compared to sucrose at wide concentration range; and 3) investigating the presence of sweetness synergisms in binary sweetener mixtures. The panelists evaluated sweetness and other sensory characteristics of sweeteners using descriptive analysis. Based on the modeled curve derived from step 1, the concentration of each sweetener with sweetness intensity equal to 2.5% or 2.8% sucrose was calculated for milk and coffee systems, respectively. For the sweetness synergism study, one type of intense sweetener was mixed with one type of bulk sweetener, each eliciting 2.5% or 2.8% equi-sweetness to sucrose, and compared with 5% sucrose added to a milk system or 5.6% sucrose added to a coffee system. The sweetness potencies of bulk sweeteners generally increased whereas the sweetness potencies of intense sweeteners decreased as the concentration increased. The binary sweetener mixtures mostly showed additivity in milk and suppression in coffee system rather than synergism when the concentration dependent nature of sweetness potency for each sweetener was taken into account.

1. Introduction

Taste synergism refers to eliciting higher taste intensity when two or more taste substances are mixed compared to the taste intensity of each individual substance summed together (Hutteau, Mathlouthi, Portmann, & Kilcast, 1998). The synergism present when MSG and IMP/GMP are mixed is one well-known example. Synergism between taste substances has commercial significance in food production, as reducing the amount of ingredients added to target food systems can reduce production costs (Lawless, 1998).

Low-calorie sweeteners have been widely used for decades by consumers concerned about health and calories in their daily diet. Food product developers frequently apply multiple low-calorie sweeteners rather than use a single low-calorie sweetener in formulating low-calorie products. Synergism in sweetness and improvement of sensory quality are expected advantages of mixing sweeteners (Portmann & Kilcast, 1998). Studies have reported that using multiple sweeteners in a food system can suppress off-flavors (e.g., bitterness, astringencies) elicited by sweeteners such as stevia or erythritol (Belščak-Cvitanović et al., 2015; Beyts & Latymer, 1985; Heikel, Krebs, Köhn, & Busch-Stockfisch, 2012; Mona & Wafaa, 2005; Portmann & Kilcast, 1998; Wolf, Bridges, & Wicklund, 2010). Schiffman, Sattely-Miller, and Bishay (2007) showed that the time to reach maximum sweetness is reduced with multiple sweeteners compared to a single sweetener. Finding the optimal combination of low-calorie sweeteners can be an effective strategy to substitute sugar in foods.

Stevia is a popular, natural low-calorie sweetener extracted from *Stevia rebaudiana* Bertoni leaves. Using stevia as a single sweetener in food is difficult due to sesquiterpene lactones responsible for the distinctive bitterness (Soejarto, Compadre, Medon, Kamath, & Kinghorn, 1983). Sucralose is an intense sweetener produced from chlorination of parts of sucrose with a relatively similar sweetness and time-intensity profile to that of sucrose (De, Medeiros, Bolini, André, & Efraim, 2007). Compared to intense sweeteners, carbohydrate-based low-calorie bulk sweeteners have better sensory quality at a higher sweetness level (Gwak, Chung, Kim, & Lim, 2012). Tagatose and xylose were recently introduced to Korean consumers as low-calorie bulk sweeteners. Tagatose is an isomer of galactose eliciting relatively high sweetness intensity (0.85–0.92 time sweetness to sucrose) compared to the sweetness potency of other low-calorie bulk sweeteners. It is relatively stable in heat and exhibits similar taste and texture characteristics to that of sucrose (Roh et al., 1999). Xylose, a material known to produce xylitol, has become an attractive low-calorie bulk sweetener due to its potential health functionality of lowering blood glucose

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level (Bae et al., 2011; Moon, Lee, Jung, Park, & Yang, 2012). Another low-calorie bulk sweetener erythritol has wide application in food systems with its stability in heat and acid and a relatively high osmotic pressure, making it an appealing material for pickling.

Determining the sweetness potency of a sweetener is a critical first step to investigate the presence of sweetness synergisms. One of the 3 approaches is generally taken to determine the sweetness potency in synergism studies: 1) use the "general" sweetness potency reported in previous literature or the sweetness potency value provided by the sweetener producer (George, Arora, Wadhwa, Singh, & Sharma, 2010; Wolf et al., 2010); 2) measure the sweetness potency of a sweetener anew at a specific concentration level and food system using magnitude estimation, rating or two-alternative forced-choice method (Alcaire et al., 2014; Batterman, Beyts, & Lillard, 1995; Cardello, Da Silva, & Damasio, 1999; Heikel et al., 2012); or 3) utilize a concentration–response (C–R) curve of sweeteners to calculate the sweetness potency of a sweetener at a specific concentration level (Hutteau et al., 1998; Parke, Birch, Portmann, & Kilcast, 1999; Portmann & Kilcast, 1998; Schiffman, Sattely-Miller, Graham, Booth, & Gibes, 2000; Schiffman, Booth, Carr, Losee, Sattely-Miller, et al., 1995, 2007).

Studies have shown that the sweetness potency of a sweetener depends on the concentration level of the sweetener, applied food matrix, and tasting condition such as temperature (Esmerino et al., 2013; Fry, Yurttas, & Biermann, 2011; Fujimaru, Park, & Lim, 2012; Moraes & Bolini, 2010; Paixão, Rodrigues, Esmerino, Cruz, & Bolini, 2014). Hence, modeling the C–R curve of a sweetener in a target food matrix would be an effective procedure to accurately determine the sweetness potency to be applied in a synergism study. Choi and Chung (2014) proposed a sucrose–sweetener combined (SSC) method, which can accurately model the C–R curve of sweeteners by minimizing contextual bias that may occur during the measurement. The SSC method essentially measures the sweetness intensities of target sweetener and sucrose at various concentration levels together in one test. Then the method models each of the C–R curves of the target sweetener and sucrose based on the sweetness intensity measured in the same test set. Finally, the sweetness potency at a specific sweetener level is calculated based on the two generated C–R curves. Thus, the sweetness potency of a sweetener in this respect is the relative sweetness to sucrose at various concentrations.

Many sweetness synergism studies were carried out in an aqueous system (Cardello et al., 1999; Heikel et al., 2012; Hutteau et al., 1998; Parke et al., 1999; Portmann & Kilcast, 1998; Schiffman, Booth, Carret, al., 1995, 2000). More recently, efforts are being made to investigate the sweetness synergisms in a real food matrix, such as fruit drinks (Mona & Wafaa, 2005) and lassi (George et al., 2010). In the present study, skimmed milk and vegetable creamer added to instant coffee were used to investigate synergisms of different sweeteners since reducing sucrose levels in these systems are currently in demand among Korean consumers. One type of highly intense sweetener was mixed with one type of bulk sweetener (each eliciting 50% equi-sweetness to sucrose) and compared with sucrose added to skim milk or instant coffee. The overall experimental design is: 1. model concentration–sweetness intensity curves of sweeteners using the SSC method; 2. measure sweetness potency of sweeteners compared to sucrose at wide concentrations (milk system 1%, 2%, 3.5%, 5% and 7%; coffee system 0.9%, 2.3%, 3.7%, 5.6%, and 7.9% sucrose equivalent range); and 3. investigate the presence of sweetness synergism between two types of sweeteners based on the sweetness potency values calculated in step 2. The C–R curve of sweetener in a milk system using the SSC method was published by Choi and Chung (2014), whose results will be adapted to investigate the presence of synergism between sweeteners. Procedure and results on the C–R curve of sweeteners in milk were previously described in detail (Choi & Chung, 2014). Therefore, only a brief description of the method and results on sweeteners in milk will be provided in the present study.

2. Materials and methods

2.1. Stimuli

Three types of bulk sweeteners (xylose, tagatose, erythritol) and two types of highly intense sweeteners (sucralose and enzyme-treated stevia) were sweeteners of interest. Sucrose was used as a control sample. All bulk sweeteners and stevia were purchased from CJ CheilJedang (Seoul, South Korea), and sucralose from ESFood (Anyang, Gyeonggi, South Korea). The samples were prepared by adding an adequate amount of sweetener to skimmed milk (Seoul Milk, Seoul, South Korea) or to vegetable cream (Dongsuh Food, Seoul, South Korea) added instant coffee (Dongsuh Food, Seoul, South Korea).

2.2. Panel

Eight to ten panelists participated as descriptive panelists. All panelists were females with ages ranging from 20 to 25. They had previously participated and been trained to evaluate sweeteners in milk and coffee systems (Choi, Kim, & Chung, 2013).

2.3. Modeling concentration–sweetness intensity curves of sweeteners

2.3.1. Sample preparation

In a previous study (Choi et al., 2013), the sweetness potency values of xylose, tagatose, erythritol, sucralose and stevia were 0.63, 0.85, 0.60, 556, and 25 times that of sucrose, respectively, when compared to 5% sucrose added to skim milk and 5.6% sucrose added to a coffee system. For the milk system, five concentration levels of each sweetener corresponding to the sweetness equivalent value (SEV) of 1%, 2%, 3.5%, 5%, and 7% sucrose were calculated based on the sweetness potency values mentioned above. Samples were prepared 4 h prior to the sensory evaluation session and served at room temperature (18 ± 5 °C) to the panelists. A 40 ml sample was served in a solo cup labeled with a random 3 digit code.

For the coffee system, five concentration levels of each sweetener corresponding to the SEV of 0.9%, 2.3%, 3.7%, 5.6%, and 7.9% sucrose were calculated. Coffee was formulated by mixing 1.9% instant coffee, 5.6% vegetable cream, an adequate amount of sweetener, and boiling water. Samples were prepared 2 h prior to the evaluation and served at 80 ± 5 °C to the panelists. A 150 ml sample was served in a thermos (Zhejiang Wuyi Hongyun Cups Co., Zhejiang, China) labeled with a random 3 digit code. The panelists were instructed to pour the sample into a 50 ml ceramic cup, taste and evaluate. The concentration of sweeteners used to model the C–R curve in milk and coffee systems is shown in Table 1.

2.3.2. Sensory evaluation procedure

The experiments on milk system and coffee system were conducted separately and independently. The sucrose–sweetener combined (SSC) method developed in a previous study (Choi & Chung, 2014) was used to model the C–R curve, as it was shown to minimize the context effect that may be present during the evaluation of the samples for C–R curve modeling. The SSC method measures the sweetness of 5 levels of a specific sweetener and 5 levels of sucrose in one test set (e.g., xylose 1.6%, 3.2%, 5.6%, 7.9%, 11.1% and sucrose 1%, 2%, 3.5%, 5% and 7% in the milk system). The regression models are produced based on the C–R curve measured for both sucrose and target sweetener. Then, sweetness potencies of a sweetener at various concentrations were calculated from the regression models of sweetener and sucrose.

Reference standards for sweetness as well as other sensory attributes were used to train the panelists and evaluate the samples to accurately measure the sweetness intensity of the samples and avoid the dumping effect (Tables 2 and 3). The reference standards for sweetness intensity were provided at different levels (3%, 5%, 7% and 10% sucrose solution anchored as 4, 7, 10 and 14 points). The sensory intensity of