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Anti-blooming effect of maltitol and tagatose as sugar substitutes for chocolate making

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A B S T R A C T

This study was conducted to analyze the blooming characteristics of chocolates containing maltitol and tagatose (D-tagatose) as alternative sweeteners in terms of their physical and sensory properties to determine the blooming progress of each chocolate and its typical characteristics. In the X-ray diffraction analysis, tagatose-added chocolate showed the slowest change in fat crystal formation. In the analysis of the surface characteristics of chocolates, the number of white fat crystals, the Hunter scale values, and the whiteness index increased as blooming proceeded. In the results of the sensory evaluation the bloom area, bloom color, crumbliness, grittiness, bitterness of taste, and powderiness of after-feel increased, but hardness, chewiness, sweetness of taste, overall flavor intensity, and cocoa flavor decreased as blooming proceeded ($p < 0.05$). The overall results indicated that tagatose-added chocolate showed the lowest blooming progress. These results presented basic information regarding making chocolate with anti-diabetic sweeteners that have good stability for bloom formation.

1. Introduction

Chocolate is the one of most popular foods worldwide. Recently, as the bioactive function of chocolate is discovered, its demand and distribution is on the increase in line with the well-being trend (Yu, Kim, Rho, Sohn, & Cha, 2007). Accordingly, storage of chocolate becomes more important after production until it reaches the consumer. A typical method to enhance storage stability of chocolate is tempering, which is a process to adjust the crystallization of cocoa butter into a desirable form in physical and sensory terms. If chocolate is heated over 50 °C to melt all fat crystals and lowered to a temperature of 26–28 °C, α or β' type fat crystals are made, which can achieve nucleation even with low energy. If the temperature is raised back again to 31–32 °C, the unstable crystals disappear and the most desirable form, βV, becomes dominant (Lonchampt & Hartel, 2006). As finished chocolate products which completed the tempering process retain relatively high amounts of fat and sugar, improper storage can cause blooming phenomenon, which is blurring of surface with white spots (Frazier & Hartel, 2012). Though the reason has not been clearly identified, it is generally known as a phenomenon of having thin grayish white film or white spots on the surface of chocolate due to crystallization problems from improper tempering or the expansion of fat generated from the chocolate structure, depending on the storage temperature and humidity condition (Kim, 2013). Even if the blooming phenomenon is known to be harmless to human body, it is regarded as the greatest defect in the modern chocolate industry by giving rise to changes in surface and fat crystal structures (Afoakwa, Paterson, Fowler, & Vieira, 2009).

As cacao has strong bitter taste, making chocolate with cacao requires the use of sweeteners. Though sugar has been mainly used in chocolates so far, the excessive intake of sugars could rise risk of some diseases such as tooth cavities, diabetes, and obesity by the side effect (Kim & Chun, 2000; Kim, 2013; Moon & Jang, 2004; Song, Lee, & Kim, 2004). Hence, there have been increasingly frequent attempts to replace sugar with other alternative sweeteners. The application of these sweeteners, however, requires

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review on the physical, chemical and sensory properties of finished products (Ryu, Kim, Lee, Son, & Surh, 2012). Maltitol is a non-carcinogenic alternative sweetener with 90% of the sweetness and 50% of the calories of sugar as a disaccharide sugar alcohol, which is made from a α-1,4 glycosidic bond between glucose and sorbitol (Washburn & Christensen, 2012). Since it has a heat-resisting property which does not decompose over 200 °C, strong flavor consistency, and a decay-preventing effect as it is not fermented by microorganisms that forms tooth plaque (Kim, 2013), it is widely used in the production of sugarless candies, chocolates and ice creams (Washburn & Christensen, 2012). Tagatose (D-tagatose) is a natural ketohexose and a reducing sugar, which is an isomer of D-galactose and D-arabinose. It is also known as a functional sweetener, since it has intestinal regulation function and reduces blood sugar by improving the symptoms of type-2 diabetes. Its sweetness is known to be 92% that of sugar and has a sweet taste that is the most similar to sugar among existing sweeteners and is widely used as an enhancer, texturizer, and stabilizer (Shourideh, Taslimi, Azizi, & Mohammadifar, 2012).

There is a lack of studies on the quality of chocolates made with these alternative sweeteners and on the differences in physical properties when the blooming phenomenon is induced. In particular, studies on products using tagatose are highly required as it is new alternative sweetener. Therefore, the purpose of this study was to analyze physical and sensory properties of chocolates made with sugar or maltitol and tagatose as alternative sweeteners by inducing blooming. Based on this approach, we attempted to reveal differences in the resistance against blooming and typical sensory properties of each chocolate.

2. Materials and methods

2.1. Materials for experiment and manufacturing of samples

To make chocolates, Ghanaian Forastero cacao beans harvested in 2014, white sugar (CJ, Incheon, Korea), tagatose (NuNaturals, Eugene, OR, USA), maltitol (Roquette, Shanghai, China), cocoa butter (ECC NV, Malle, Belgium), and emulsifier (SOLAE LLC, St. Louis, MO, USA) were used. Cacao beans were roasted for 25 min at 200 °C, then cooled, and their inside and outside skins were eliminated and crushed with a nib separator (THNP-10, Taehwan, Paju, Korea). Then, using a mixer (TOUCH&GO 2, Vitamix, Cleveland, OH, USA), they were more finely crushed into less than 200 μm to be used as cacao nib. Three kinds of sweeteners (sugar, maltitol, tagatose), cocoa butter, and emulsifier (lecithin) were added in a predetermined ratio to the cacao nib (Table 1). Sweeteners were mixed considering relative sweetness, so that the sweetness of final products was identical. The mixture was made into couverture by conching it at a speed of 60 rpm for 48 h at 50 °C using a conche (THCM-02, Taehwan, Paju, Korea). Couverture was put in a 3 L airtight container (LOCK&LOCK, Asan, Korea) and stored at 4 °C for one week. Then, it was tempered in the order of 50 °C, then 27 °C, then 31 °C, and 20 g of couverture was poured in a 1-inch cube frame, which were then cooled at room temperature and finally made into chocolates. The chocolates were double-sealed with foil and stored in incubators (VB-150B, Vision Biotech, Incheon, Korea) set at 18 °C and 30 °C for the experiment. Conditions to induce blooming phenomenon were established by partially modifying those of preceding studies (Ali, Selamat, Che Man, & Suria, 2001). Blooming-inducing cycles were set at one-day intervals (18 h in 18 °C, 6 h in 30 °C) and the cycles were repeated 10, 20, and 30 times on the samples, which were then stored at 15 °C. The 0 time sample was the one without inducing blooming. In the results of the experiment, samples which underwent these processes were named depending on the sweeteners used (S-sugar, M-maltitol, and T-tagatose) and the numbers of cycles were added after them.

Table 1
Ratio of ingredients for making chocolate products.

Ingredients	(Unit: g)		
	SC[a](1)[b]	MC(0.9)	TC(0.92)
Cacao nib	44.91	44.91	44.91
Cocoa butter	10.78	10.78	10.78
Sweetener[c]	43.81	48.68	47.62
Lecithin	0.52	0.52	0.52
Total	100.02	104.89	103.83

[a] SC: sugar-added chocolate, MC: maltitol-added chocolate, TC: tagatose-added chocolate.
[b] Numbers mean relative sweetness based on sugar.
[c] Amounts of sweeteners of each group was adjusted to present same sweet intensity refer to their relative sweetness indices.

2.2. Analysis on fat crystals using X-ray diffraction (XRD)

To look into construction of the polymorphic fat crystals which compose chocolate, X-ray diffraction was conducted using powder X-ray diffractometry (powder X-ray diffractometry D8 Advance, Bruker, Karlsruhe, Germany) ($\lambda = 1.54$ Å) and detailed conditions were applied by modifying the method of a preceding study (Hodge & Rousseau, 2002). To prevent interruption by sweetener crystals, removal of sugar was conducted (Cebular & Ziegleder, 1993). To prevent the structure of fat crystals from being transformed, chocolate was stored at 4 °C for 2 h and was cut to be less than 0.5 mm in size, and put into 500 mL of purified water at 4 °C. Then it was left at 180 rpm for 4 h, filtered with filter paper (Whatman No.1) and dried for 12 h. Afterward, experimental results were acquired by using an X-ray (Cu-K ray) in the range of 3–30° 2θ at 25 °C, and crystal forms were judged by referring to existing analyzed values on typical fat crystal forms.

2.3. Surface analysis using stereoscopic microscope and field emission scanning electron microscope (FE-SEM)

Overall surfaces of the samples were observed by the using reflected light of a stereoscopic microscope (Stereomicroscope stemi-DV4, Carl Zeiss, Oberkochen, Germany). Magnification was ×8, and in order to facilitate analysis of all photos, a 100 μm standard rod was inserted. In addition, to observe the fine surface structure, a field emission scanning electron microscope (Field Emission Scanning Electron Microscope SUPRA 55 VP, Carl Zeiss, Oberkochen, Germany) was used. Chocolate samples were cut into the size of 5 × 5 × 2 mm, attached and fixed on a stub with carbon tape, plated with platinum for 150 s by using a coater (Sputter coater BAL-TEC/SCD 005, BAL-TEC AG, Balzers, Liechtenstein), and observed. The accelerating voltage was 2 kV and the magnification was ×250.

2.4. Color index and whiteness index

Color index of the surface of each sample was measured 3 times by using a colorimeter (CM-5, Konica Minolta, Tokyo, Japan) set at $\Phi = 8$ mm. Color space was marked as the average value of Hunter's color system (Youn & Lee, 2012). The D65 illuminant was used and observer angle was 10°. A standard whiteboard used was L = 97.04, a = −0.09, b = −0.24. Meanwhile whiteness index (WI), which is an index used to confirm the degree of progress of the blooming phenomenon, was calculated by referring to the equation (Lohman & Hartel, 1994).