The effect of bulking agent and type of chocolate on the physicochemical characteristics of sucrose-free chocolate using stevia as a sweetener

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Abstract. The aim of this research is to find out the effect addition of bulking agents on the physicochemical properties of sucrose-free chocolate products using stevia as a sweetener. Sucrose-free chocolate using stevia as a sweetener needs various bulking agents to make the same physical characteristics as the commercial chocolate. The alternative bulking agent that could be used for sucrose-free chocolate is the combination of inulin and erythritol or inulin and sorbitol. The combination of inulin and sorbitol as a bulking agent on dark chocolate can improve the protein and fat content and lower the moisture content than the reference chocolate. Milk chocolate with inulin and erythritol as a bulking agent has a higher protein, fat content but lower carbohydrate content than commercial chocolate. A high concentration of inulin will increase the level of carbohydrate content both in dark and milk chocolate. Higher concentrations of sorbitol can decrease the fat content on sucrose-free dark chocolate. Erythritol with a high concentration will increase the color brightness and reduce moisture. Higher concentrations of inulin will decrease the fat content on sucrose-free milk chocolate.

1. Introduction
Chocolate is one of the most popular food products because it has a unique taste [1]. Chocolate in the food industry has several types, such as milk chocolate, dark chocolate, white chocolate, chocolate jam, etc. Based on research by Yeh et al. [2], most participants consumed milk chocolate with a larger serving amount compared to dark chocolate because of the higher sucrose content in milk chocolate, so that it has a sweeter taste than dark chocolate. The high level of public awareness of health makes people prefer healthier foods. People who have specific disease problems such as diabetes or overweight are also required to reduce chocolate products' consumption. The strategy for chocolate products to be consumed by all groups is by making healthy chocolate products. This can be done by replacing raw materials with sweeteners that are friendly to health, such as stevia.
Stevia sweetener has zero caloric value and does not contain carbohydrates, so it is safe for people with diabetes, people who are doing weight management and healthy lifestyles [3]. However, stevia sweetener does not have several functions of sucrose in chocolate, such as bulking agent and texture modifier [4].

Inulin is a carbohydrate known as fructan, which has $\beta 2 \rightarrow 1$ glycosidic bond. The $\beta 2 \rightarrow 1$ bonds cause the inulin cannot be digested by enzymes in the human intestine and form the fructan class of dietary fiber. These properties cause inulin to be functional, such as being able to function as a bulking agent. Inulin has a low calorific value (1.1-1.5 kcal / g), making it suitable for diabetics [5]. Erythritol is a 4-carbon sugar alcohol derived from the fermentation of glucose and sucrose by *Trichosporonoides megachilliensis*. Erythritol has humectant and volume-enhancing properties that can provide a laxative effect when consumed in high amounts [6]. The FDA labels erythritol with a calorific value of 0.2 kcal / g, some countries such as Japan label it as 0 kcal / g. When consumed, erythritol does not cause an increase in blood glucose and insulin [7]. Sorbitol is a sugar alcohol found in several dried fruits such as grapes, prunes, dates, raisins, apples, and pears [8]. Sorbitol has a lower calorie content compared to sucrose, which is 2.6 kilocalories per gram. The level of sweetness of sorbitol can reach 60% of sucrose [9]. Sorbitol has a synergistic effect with other sweeteners that can produce a tastier sweet taste [10]. This research aims to find out the effect of a bulking agent on the physicochemical properties of sucrose-free chocolate products using stevia as a sweetener.

2. Materials and Methods

2.1. Materials
The ingredients used in the process of making milk chocolate are chocolate liquor (Vicco), cocoa butter (Vicco), full cream milk powder (Indomilk), stevia sweetener (Stevigrow), soy lecithin (Lansida), vanilla (Koepoe Koepoe), baking soda (Koepoe Koepoe), inulin (Orafti GR), sorbitol (Orafti GR) and erythritol (Club Sehat).

2.2. Chocolate production
The chocolate-making process's first step is to smooth the chocolate liquor with a chocolate concher for 5 hours. The refined liquor chocolate was then mixed with other ingredients: powdered milk, sugar, bulking agent, and mashed fat using a ball mill for 5 hours with a temperature of 60°C and a speed of 40 rpm. During the mixing and refining process with the ball mill, the vanilla and soy lecithin were added 2 hours before the process was stopped. After 5 hours, the temperature on the appliance was turned off. The chocolate was kept until the temperature drop to 30°C. The chilled chocolate then enters the tempering stage. Tempering was done by using the tabling method.

The tabling method is a tempering technique by spreading melted chocolate on a cold table such as a marble slab or other cold, smooth, and non-porous surfaces [11]. The marble countertop used was less than 23°C and can be lowered by placing it in the freezer for a few minutes. The chilled chocolate was reheated until the temperature reaches 45°C. 3/4 of the chocolate was poured on the marble table and stirred using a spatula until thickened and slightly hardened. The chocolate was then put back in the container containing the remaining chocolate and stirred until blended. The chocolate dough temperature was checked; if it does not exceed 28 °C, the chocolate dough can be molded into a mold and let stand overnight. After sitting overnight, the chocolate can be removed from the mold and packaged.

The preliminary research conducted was to make milk chocolate and dark chocolate according to the predetermined formula. The concentrations of inulin, sorbitol, and erythritol as bulking agents in the formulation can be seen in Table 1.
Table 1. Variation of bulking agents in milk chocolate and dark chocolate formulations.

| Formulations | Inulin Concentrations (%) | Erythritol Concentrations (%) | Sorbitol Concentrations (%) |
|--------------|---------------------------|-------------------------------|----------------------------|
| A¹           | 25                        | 75                            | -                          |
| B¹           | 50                        | 50                            | -                          |
| A²           | 25                        | -                             | 75                         |
| B²           | 60                        | -                             | 40                         |

Information: (¹) milk chocolate, (²) dark chocolate

Table 2. Composition of milk chocolate and dark chocolate.

| No | Variants       | Cocoa Liquor (%) | Cocoa Butter (%) | Milk Powder (%) | Inulin (0–18.5) | Sorbitol (0–25) | Erythritol (0–25) | Lecithin (%) | Baking Soda (%) | Vanilla (%) |
|----|----------------|------------------|------------------|-----------------|----------------|----------------|-------------------|--------------|----------------|-------------|
| 1  | Dark Chocolate | 39               | 31               | 11.5            | 0–18.5         | –              | –                 | 0.3          | 0.3            | 0.1         |
| 2  | Milk Chocolate | 32.5             | 20               | 22.5            | 0–25           | 0–25           | –                 | 0.3          | 0.3            | 0.1         |

2.3. Methods

2.3.1. Color measuring

Bar chocolate color was measured with a color reader calibrated against the white reference standard. SCE (Specular Light Excluded) mode was used with the colors represented in the CIELAB system L*, a* and b*: L*, luminance from 0 (black) to 100 (white); and a (green to red) and b (blue to yellow).

2.3.2. Determination of water content

The determination of water content was carried out using the gravimetric method. The samples were heated in an oven for three hours with a temperature of 100ºC. After three hours, the container was closed and transferred to a desiccator and the weight was measured as soon as the container temperature has decreased or to about room temperature. Then the percent weight loss was calculated as the water content lost.

2.3.3. Determination of total protein content

Total protein content in chocolate products was analyzed using the Kjeldahl method. The chocolate sample was mashed, weighed 1 g, put in a Kjeldahl flask, and then added the K₂SO₄ reagent, CuSO₄, and H₂SO₄. The digestion was carried out until the sample turns Tosca green. After changing color, the process is stopped and let cool for 20 minutes. Furthermore, the sample was added with 25 ml of distilled water, 50 ml of 40% NaOH, and a few grains of boiled stones and then distilled. The distillation results are collected in an erlenmeyer containing 30 ml of H₃BO₃ solution which has been added with three drops of the BCC-MR indicator. The distilled distillate is then titrated with a standard solution of 0.1 N HCl until the color of the solution turns pink. Furthermore, the calculation of protein content is carried out.

\[
\% N = \frac{(ml HCl (sample-blank)) \times N HCl \times 14.008 \times 100\%}{(sample weight (g)) \times 1000}
\]  \hspace{1cm} (1)

\[
\% \text{ Protein} = \% N \times \text{correction factor}
\]  \hspace{1cm} (2)
2.3.4. Determination of carbohydrate content
Carbohydrate content was calculated from moisture, ash, fat, and protein content using the following formula:

\[
\% \text{Carbohydrates} = 100\% - (\% \text{fat} + \% \text{protein} + \% \text{ash} + \% \text{water})
\]  
(3)

2.3.5. Determination of fat content
Fat content was analyzed using the soxhlet extraction method. First, the fat flask was placed in the oven, then cool it in a desiccator and weigh. Extraction was carried out for six hours until the solvent dropped back down through the chiffon into the clear fat flask. The extraction product was then distilled to separate the petroleum benzene and fat. The fat squash was then re-roasted for one hour. The fat content can be calculated using the following formula:

\[
\text{Fat content} = \frac{w_3 - w_2}{w_1} \times 100\%
\]  
(4)

Information: 
- W1 = weight of the sample before drying (g)
- W2 = weight of empty fat pumpkin (g)
- W3 = weight of container and sample that has been dried (g)

3. Results and Discussion

3.1. The effect of treatments
There is a color difference between dark chocolate and milk chocolate sucrose-free samples. The dark chocolate color is lower than milk chocolate. The L values for dark chocolate were 15.33 and 14.37, while those for milk chocolate were 15.70 and 14.60. This shows that dark chocolate has a darker color than milk chocolate. Based on research by Lin et al. [7] in making cookies, high concentrations of erythritol will make the surface of the cookies brighter. This is probably because erythritol is a polyhydroxyl component that is not a reducing group so that it will not experience a Maillard reaction and caramelization, which causes brownish color. Using erythritol, the higher the inulin concentration, the higher the brightness value.

\[
\begin{array}{c|c|c}
\text{Type of chocolate} & \text{Lightness (L* value)} \\
\hline
\text{Milk Chocolate} & 15.5 & 15.3 \\
\text{Dark Chocolate} & 15.1 & 14.9 \\
\end{array}
\]

\[
\begin{array}{c|c|c}
\text{Type of chocolate} & \text{Lightness (L* value)} \\
\hline
\text{Milk Chocolate} & 15.5 & 15.3 \\
\text{Dark Chocolate} & 15.1 & 14.9 \\
\end{array}
\]

**Figure 1.** Comparison of the lightness of milk chocolate and dark chocolate.

The difference in color between dark chocolate and sucrose-free milk chocolate can be caused by the addition of sorbitol, which accelerates caramelization and the Maillard reaction, thereby accelerating the formation of the chocolate color [12]. Previous studies have also reported that replacing sucrose with inulin and polydextrose results in darker chocolate [13]. Shourideh et al. [14] reported darker chocolate
for a dark chocolate formulation containing 100% inulin. Inulin absorbs moisture, light scattering, and less brightness, making chocolate appear darker. Aini et al. [15] reported the chocolate sample with 20% inulin as the brownest and had the lowest L * value among the other texturizing ingredients in milk chocolate. Sorbitol is a sugar alcohol that is stable at high temperatures and does not undergo Maillard reactions at high temperatures [15]. The Maillard reaction will produce melanoidin compounds that can create a brown color in food products.

3.2. Chemical characteristics
Table 3 presents the fat, protein, carbohydrate, moisture content, and lightness properties of sucrose-free chocolate.

| Types of Chocolate | Fat content (%) | Protein content (%) | Carbohydrate (%) | Moisture (%) |
|--------------------|-----------------|--------------------|------------------|-------------|
| Milk Chocolate A   | 44.39           | 8.6               | 35.1             | 1.31        |
| Milk Chocolate B   | 44.62           | 9.12              | 41.38            | 1.8         |
| Dark Chocolate A   | 55.18           | 7.51              | 30.02            | 0.71        |
| Dark Chocolate B   | 56.84           | 8.04              | 24.87            | 1.23        |

Figure 2. Physicochemical properties comparison of milk chocolate and dark chocolate.

3.2.1. Fat content
It can be seen from Table 3 that the fat content in dark chocolate with the same composition as milk chocolate has a higher value. This difference is because dark chocolate uses a higher proportion of cocoa liquor. In addition, the effect of bulking agents can determine the fat content in chocolate. According to Grumezescu and Holban [16], inulin can reduce fat levels in yogurt. Inulin will form an elongated gel structure between the casein micelle aggregates to replace the fat content, which functions as a connecting agent. Galanakis [17] also stated that inulin could be used as a substitute for fat because it has stable tissue and can resemble the texture of fat in low-fat meat products. The addition of inulin to sausage products will reduce fat content, improve texture and sensory properties.

3.2.2. Protein content
The table shows that the protein content in milk chocolate is higher than dark chocolate. This variance is probably due to erythritol, which does not affect the protein content in chocolate. Lin et al. [7] who
used erythritol as a substitute for sucrose in making Danish cookies are not much different from using sucrose. Based on research results Berizi et al. [18], the increasing concentration of inulin as a substitute for fat in sausages, the protein content decreased but did not differ too much. This property allows inulin in high concentrations to reduce protein levels.

3.2.3. Carbohydrate content
The results of Berizi et al. [18] research stated that the use of sorbitol in sucrose-free dark chocolate can reduce carbohydrate levels in the product because the calorie content of sorbitol is lower than sucrose, which is 2.6 kilocalories per gram. Sorbitol also has a low glycemic index (GI = 9) which does not increase blood sugar levels and insulin levels significantly [9]. Berizi et al. [18] stated that the increasing concentration of inulin as a substitute for sucrose in candy carbohydrate content also increased. This variation may be caused by erythritol, which is a form of carbohydrate. So that if the higher the erythritol concentration is added, the carbohydrate content will also increase.

3.2.4. Moisture content
In general, sugar alcohols/polyols are very soluble in water to very hygroscopic. However, erythritol shows very low hygroscopic properties [19]. Erythritol is also good for preventing moisture adsorption on fruit pieces, fruit bars, and flour candy. If the erythritol concentration increases, the moisture absorption will be less, so that the water content will decrease. According to research by Shourideh et al. [14], in milk chocolate with an inulin concentration below 50%, the water content of the product did not increase. In contrast, if the concentration increased, the water content would increase. Farzanmehr and Abbasi’s [20] research in Aidoo et al. [13] also stated that inulin would increase water content if used in high concentrations.

The higher water content is caused by sorbitol, which is hygroscopic and can bind free water in the material. The higher the addition of sorbitol in a food, the more free water is bound [21]. When sorbitol is added to food, there will be a covalent bond between the O and H sorbitol groups with the O and H groups in water [22]. When there is heating in the manufacture of sucrose-free dark chocolate, the water is evaporated slightly. This is because when measuring the moisture content in chocolate, it will produce more water content when compared to sucrose.

4. Conclusions
The combination of inulin and sorbitol as a bulking agent on dark chocolate can improve the protein and fat content but lower the moisture content than the reference chocolate. Milk chocolate with inulin and erythritol as a bulking agent has a higher protein and fat content but with lower carbohydrate content than the reference chocolate. A higher concentration of inulin will increase the carbohydrate content of both dark and milk chocolate. A higher concentration of sorbitol will decrease the fat content on dark chocolate. A higher concentration of erythritol will increase color brightness and reduce moisture. A higher concentration of inulin will decrease the fat content on sucrose-free milk chocolate.

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