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Original Article

Comparative Study of Sucralose and Stevia Substitution for Sweeteners in Uli Banana Jam as a Functional Food

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Abstract - *Bananas are a type of flora that grows widely in Indonesia. Apart from using the flesh, the part of the banana that is still rarely used is the banana peel. One banana-based product that is still rarely found is jam. Jam can be considered a functional food if it uses ingredients that can enhance nutrition and reduce unhealthy components. Making jam requires citric acid to form a consistent gel, and lemon juice can be used as a natural source of citric acid. Jam contains high sugar, and sucrose sweeteners are substituted with sucralose and stevia to reduce its negative health effects. Sucralose is an artificial sweetener, while stevia is a natural sweetener. Both sweeteners are low in calories. This research was conducted to determine banana jam's physicochemical and organoleptic properties with sweetener substitution. The method used in this research is experimental and discussed descriptively. The results showed that sweetener substitution affected L* and a* values, hardness, cohesiveness, adhesiveness, spreadability, syneresis, moisture content, and antioxidant activity. However, it did not affect the b* value and pH level. The research significantly impacted the organoleptic properties of color and spreadability, but did not significantly affect the real effect on aroma, texture, taste and aftertaste.*

Keywords - *Banana, Organoleptic test, Physicochemical properties, Stevia, Sucralose.*

1. Introduction

Nowadays, people are more concerned about health, and one of the ways to reduce health issues is by consuming functional foods. Functional foods are food or beverage products with nutritional values and the ability to improve health [1]. A characteristic of functional foods is that they must be consumed regularly and be a part of everyday diet, such as fruit jam. Jam is a processed product made from crushed fruit and sucrose and cooked until it forms a thickened gel [2]. A fruit that is rarely processed into jam is the banana. Bananas are plants that grow easily in any season, and in Indonesia, their production reached 9,26 million tons in 2024 [3]. The functional value of jam can be increased by using ingredients like lemon and banana peel. Lemon addition is used as a citric acid replacement to form a consistent gel because it contains around 5% citric acid [4]. Besides citric acid, lemon juice also has an antioxidant range from 32.79 ppm to 263.63 ppm [5]. Banana peels are still rarely utilized even though they represent 35-40% of the fruit and contain pectin, which can be used to stabilize jam. The IC_{50} value of the banana peel extract is 0.0646 mg/mL [6]. The texture and flavor of jam are significantly influenced by adding sugar, which helps achieve the desired consistency and sweet taste [7]. However, using high amounts of sugar can have harmful effects, such as diabetes. According to the International Diabetes Federation (IDF), the number of people with diabetes in the South East Asia Region is 106.9 million [8]. One way to reduce the negative effects of sugar is by substituting it with low-calorie sweeteners. Low-calorie sweeteners that can be used are sucralose, which is 450-600 times sweeter than sucrose [9] and stevia, which is 250-300 times sweeter than sucrose [10]. Therefore, a study is needed on the substitution of sucralose and stevia sweeteners in functional banana uli jam through physicochemical and organoleptic testing.

2. Materials and Methods

2.1. Materials

Uli bananas were obtained from a local farm in Dago area (Bandung, Indonesia), sucralose and stevia were purchased from Kanbo and NaturalCo, and sucrose and lemon were purchased from the local market. All chemicals used were of analytical grade.

2.2. Jam Formulation

The formulations include 3 main components: the ratio between banana flesh. It is skin (90:10, 80:20, 70:30, 60:40, 50:50) using sensory analysis, lemon concentration (10%, 15%, 20%, 25%) based on pH level, and sweeteners substitution (25%) based on degrees Brix.

The final formulation was determined from the results of preliminary research presented in Table 1.

Table 1. Final formulation of functional jam

Formulations	Components					
	Banana pulp (g)	Banana peel pulp (g)	Lemon juice (ml)	Sucrose (g)	Sucralose (g)	Stevia (g)
SC	80	20	38,75	55	0	0
SL	80	20	38,75	41,25	0,023	0
SV	80	20	38,75	41,25	0	0,069

2.3. Preliminary Study

A preliminary study was conducted to determine the formulation ratio between banana pulp and peel, lemon juice, and varying concentrations of sweeteners. Measurements, including Brix value and pH, were performed. The resulting jam formulations were then subjected to sensory evaluation by semi-trained panellists (students who have passed the sensory evaluation course), and the most preferred formulation was selected based on the results. The experimental procedures are detailed below:

2.3.1. Determine the Ratio of Banana Pulp to Peel

Banana pulp and peel were prepared in varying ratios of 90:10, 80:20, 70:30, 60:40, and 50:50 (w/w). Each mixture was combined with pre-weighed lemon juice and sugar. The ingredients were stirred continuously while being heated, simultaneously with the sterilization (100ºC, 25 min.) of a pre-washed glass jar. Sensory evaluation was conducted to assess panellist acceptance.

2.3.2. Determination of Lemon Juice Concentration

Lemon juice concentration formulations varying at 10%, 15%, 20%, and 25% of the total weight were prepared. Sugar, banana pulp, and peeled banana were weighed and incorporated into each formulation. The ingredients mentioned were then heated under constant stirring until a homogeneous mixture was achieved. The resulting products were analyzed for pH level, and the formulation meeting the standard pH level was selected for further analysis.

2.3.3. Formulation of Sweetener Substitution

The formulation of sweetener substitution was determined by preparing and weighing banana pulp and banana peel purees. Lemon juice was also prepared at concentrations of 15% (w/w) and 25% (w/w) based on the total mixture. Sweeteners prepared were 30% granulated sugar, 25% sucralose, and 25% stevia, with sucralose and stevia amounts adjusted based on their relative sweetness levels. Glass jars were thoroughly washed, drained, and sterilized (100ºC, 25 min.) prior to filling. Sweeteners mentioned were then incorporated with banana and lemon juice. The resulting jams were subjected to Brix analysis to evaluate soluble solids content.

2.4. Jam Preparation

Banana fruits were washed, peeled, and separated into the flesh and peel. The flesh was sliced (1-1,5 cm thick), blended (5 min.), and strained with commercial mesh. The peels were boiled (10-15 min.), chilled, scraped, and blended (5 min.). To obtain lemon juice, lemon fruits were washed, sliced in half, and squeezed. Sucrose (30% & 55%) and sucralose and stevia (25%) were weighted based on relative sweetness compared to sucrose. All the ingredients mentioned were combined, stirred above the heated stove while the glass jar was sterilized (100ºC, 25 min.).

2.5. Physicochemical Analysis

2.5.1. Color

The colors of the jam were measured using a spectrophotometer CM-5 with the CIE-Lab method [11]. Spectrophotometers were calibrated using a white tile and using illuminant D65. L* value measures lightness to darkness, a* measures redness to greenness, and b* measures yellowness to blueness. Measurements were done in duplicates and repeated twice.

2.5.2. Texture

The texture of the jam was analyzed using a texture analyzer (TA.XT Plus) and measured for hardness, cohesiveness, and adhesiveness parameters [12]. Samples were placed at the center of the probe. The pre-test, test, and post-test settings were 1 mm/s; target mode, distance of compression of 2,5 mm; time 5,0 sec.; trigger type, auto (force), trigger force 1 g. All the parameters mentioned were processed with Exponent Light software. Duplicate samples for each sample were made and repeated twice.

2.5.3. Spreadability

The spreading power of jam was measured using the method from [13]. Jams were weighed (3 g) and placed on a bread knife. The samples were spread on bread until they reached the furthest distance, then measured in cm.

2.5.4. Syneresis

The syneresis level of the jam was measured by placing the samples inside the refrigerator for 24 hours [14]. Samples were weighed for 30 grams as sample weight, filter paper was also weighed in grams, and the samples were then placed on the filter paper.

The samples were placed inside a measuring cup and left in the refrigerator for 24 hours, then the sample was weighed in grams. The syneresis level was measured using the equation mentioned below.

$$\text{Syneresis (\%)} = \frac{\text{Weight of initial sample} - \text{Weight of sample after storage}}{\text{Weight of initial sample}} \times 100$$

2.5.5. pH Level and Moisture Content

AOAC standards were used to determine pH level and moisture content. pH meters were standardized using pH 4 and 7 buffer solutions. Samples were measured for 50 ml and mixed thoroughly. pH levels were then taken with a pH meter. For moisture content, samples were analyzed by drying at 100-105ºC for 24 hours and measured until they reached constant weight.

2.5.6. Antioxidant Activity

Functional jams (5 g) were ultrasonically extracted for 30 minutes with 70% methanol (30 ml) at room temperature and centrifuged at 4500 rpm for 15 minutes [15]. The steps were repeated twice, and the extracts were combined. The DPPH method was used to determine antioxidant activities [16]. Sample extracts were diluted in DPPH solution, incubated in a dark room for 30 minutes, and measured using a UV-Vis spectrophotometer (517nm wavelength). Antioxidant levels were measured using the equation below.

$$\%\text{inhibition} = (A_{control} - A_{sample})/A_{control}$$

A= Absorbance

2.6. Sensory Analysis

The sensory analysis of uli banana functional jam without substitution (SC), uli banana functional jam with 25% sucralose substitution (SL), and uli banana functional jam with 25% stevia substitution (SV) was made by a panel of 30 testers. The evaluation was carried out in a sensory laboratory and based on 6 parameters: aroma, spreadability, texture, color, taste, and aftertaste. It was also based on 5 point hedonic scale (5 = liked very much, 4 = liked, 3 = slightly disliked, 2 = disliked, 1 = disliked very much) with detailed explanations on each parameter. The results were statistically analyzed using Duncan's Multiple Range test (DMRT).

2.7. Statistical Analysis

The results are shown as mean ± standard deviation for all collected data. Analyses were performed using SPSS statistical program software version 25 and analyzed using General Linear Model, Univariate. Experimental data were subjected to Duncan's Multiple Range test, using $p \leq 0.5$ as significant differences for each sample.

3. Results and Discussion

3.1. Physical Characteristics

The results of color, texture, spreadability, and syneresis of uli banana functional jam are presented in Table 2. Substitution of sweeteners had a significant impact on the physical properties of functional jam. The color on SC appears to be darker and redder due to caramelization and browning caused by sugar; the more sugar is added, the darker the color [17]. Substitution of sample SL and SV have a lighter color because both sweeteners are more stable at high temperature [18, 19]. The yellowness levels on each sample have no significant difference because the banana amounts are the same. Texture analysis results show significant differences in hardness, cohesiveness, and adhesiveness level. SC has the lowest hardness level, which is caused by a high level of sucrose added. Added sugar concentration of more than 60% can cause water to escape from the jam, resulting in a lower hardness level [20]. Cohesiveness is the interaction between the ingredients added. The adhesiveness level of SL and SV shows similar results due to the addition of a similar amount of sucrose. It is said that stevia does not significantly affect adhesiveness [21]. The spreading ability of functional jam shows that SC has the highest level, while SV has the lowest. The level of pH, sugar concentration, and thickener affect the formation of gel [22]. Sugar increases pectin gel formation by attracting water molecules, which influence textural properties. SL has high solubility in water [23], but only a small amount was added, which leads to less optimal spreading power. SV does not dissolve easily in water [24], resulting in lower spreadability.

The syneresis level of functional jam can be considered syneresis-free. Jams with a syneresis level between 0-5% can be considered free from syneresis [25]. In general, sucrose has the ability to bind water (hydrophilic), thus reducing the syneresis level [26]. A higher syneresis level could be caused by insufficient pectin concentration. Sucralose is very stable in various temperatures and pH levels [23], resulting in the lowest level of syneresis.

Table 2. Physical characteristics of functional jam

Parameters	SC	SL	SV
Color			
L*	37,56±0,84^a	39,62±0,89^b	39,94±0,66^b
a*	14,12±0,30^b	11,28±0,43^a	11,38±0,53^a
b*	24,48±0,99^a	24,39±1,10^a	24,09±0,91^a
Texture			
Hardness (gf)	93,67±1,13^a	106,40±2,10^b	103,63±3,47^b
Cohesiveness	0,80±0,07^b	0,69±0,08^a	0,83±0,05^b
Adhesiveness (gs)	-50,74±2,69^a	-41,49±4,03^b	-42,63±5,68^b
Spreadability (cm)	9,33±0,24^c	8,35±0,19^b	7,9±0,18^a
Syneresis (%)	1,12±0,01^b	1,08±0,01^a	1,12±0,02^b

Note: Values presented are mean±SD. Different superscripts in the same line indicate significant differences.

3.2. Chemical Characteristics

As shown in Table 3, the substitution of sweeteners significantly affects moisture contents and antioxidant activities. There are no significant differences in pH levels. The optimum pH level for fruit jams is 3,0 – 3,7 [27]. pH level is related to syneresis, where overly acidic conditions can cause syneresis. Moisture content is related to shelf life because it could affect microorganisms to grow and decrease the quality of the jam [28]. A higher percentage of sucrose caused the moisture content to decrease because of sugar's hydrophilic ability [29]. Moisture content is also influenced

by temperature and time of cooking. Functional jam has a high level of antioxidant activities. This is caused by banana peel, which has a higher level of antioxidants than the fruit [3] and lemon, a natural antioxidant containing citric acid, vitamin C, and other volatiles [5]. SL has the highest antioxidant activity because it can sustain vitamin C concentration [30]. SV has a higher level of antioxidants compared to SC because stevia has antioxidant properties and a high level of phenolic compounds [31].

Table 3. Chemical characteristics of functional jam

Samples	pH level	Moisture content (%)	Antioxidant activity (µg/ml)
SC	3,26±0,08^{a}	38,04±0,30^{a}	14,58±0,51^{b}
SL	3,27±0,08^{a}	40,87±1,44^{b}	13,32±0,31^{a}
SV	3,22±0,10^{a}	39,11±0,93^{a}	13,57±0,50^{a}

Note: Values presented are mean±SD. Different superscripts in the same line indicate significant differences.

3.3. Sensory Characteristics

As seen in Table 4, substituting sucralose and stevia significantly affects aroma and spreadability, but aroma, texture, taste, and aftertaste have similar results. Although the overall acceptance of SC is still relatively higher than SL and SV, SL still has higher acceptance between the two sweetener substitutions. This could be due to the fact that sucralose has a taste profile and characteristics similar to sucrose.

Table 4. Sensory characteristics of functional jam

Parameters	SC	SL	SV
Aroma	3,13±0,82^{a}	3,50±0,90^{a}	3,37±1,00^{a}
Texture	3,87±0,86^{a}	4,17±0,70^{a}	3,83±0,83^{a}
Color	3,43±0,68^{c}	2,93±0,79^{b}	2,57±0,77^{a}
Taste	4,03±0,72^{a}	4,00±0,83^{a}	3,80±0,96^{a}
Aftertaste	4,47±0,57^{a}	4,37±0,56^{a}	4,43±0,50^{a}
Spreadability	3,87±1,07^{ab}	3,97±0,81^{c}	3,37±1,00^{a}

Note: Values presented are mean±SD. Different superscripts in the same line indicate significant differences.

4. Conclusion

Sucralose and stevia are both non-nutritive sweeteners commonly used as sugar alternatives, resulting in a significant alteration of the color values (L* and a*), hardness, cohesiveness, adhesiveness, spreadability, syneresis, moisture content, antioxidant activity, and sensory analysis of color and spreadability. However, it did not affect b* color value, pH level, aroma, texture, taste, or aftertaste on sensory analysis.

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