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Imitation watermelon sheet jam made from watermelon albedo with natural coloring from roselle petals (*Hibiscus sabdariffa* L) and sappan wood (*Caesalpinia sappan* L)

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ORIGINAL ARTICLES

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ABSTRACT

The sheet jam was developed by reflecting on the practicality of sheet cheese. Sheet jam can be formed with the presence of hydrocolloids. Pectin is a hydrocolloid that is naturally contained in watermelon albedo. However, the use of watermelon albedo in making imitation watermelon sheet jam requires coloring and sweeteners. This study aims to obtain the physicochemical and sensory characteristics of imitation watermelon sheet jam using watermelon albedo with natural coloring and sweetener formulations. The treatments used were two types of natural dyes (roselle and sappanwood) and sweetener formulations (fructose, honey, sucrose). The psychochemical characteristics tested were water content, reducing sugar content, total acid, and color. Sensory characteristics were tested descriptively and hedonic quality. Data analysis has been carried out using OPLS-DA, followed by OPLS, and Pearson's correlation (by SIMCA 14.1). The findings showed that the main physicochemical and sensory characteristics of imitation watermelon sheet jam were herbal aroma, fruit aroma, chewy texture, sweetness, reducing sugar, Hue (red/yellow), rollability, and overall preference. The characteristics that determine the level of preference for imitation watermelon sheet jam were rollability, sweetness, shiny appearance, and chewy taste. The sweet taste characteristic (r -0.92582) has a negative correlation with the level of preference. The presence of a doctoring agent (fructose or honey) prevents crystallization in sheet jam, which is positively correlated with preference. Coloring with Roselle and sappanwood can replace the use of watermelon flesh and can be further studied in relation to the functional characteristics that may be provided.

Key Messages:

- Formulation of sheet jams made from watermelon albedo with fructose/honey sweetener showed exhibited good rollability, shiny appearance, and chewy taste.
- The characteristics of sheet jam rollability, shiny appearance, and chewy taste were positive correlations to preference. Meanwhile, sweetness was negative correlation to preference.

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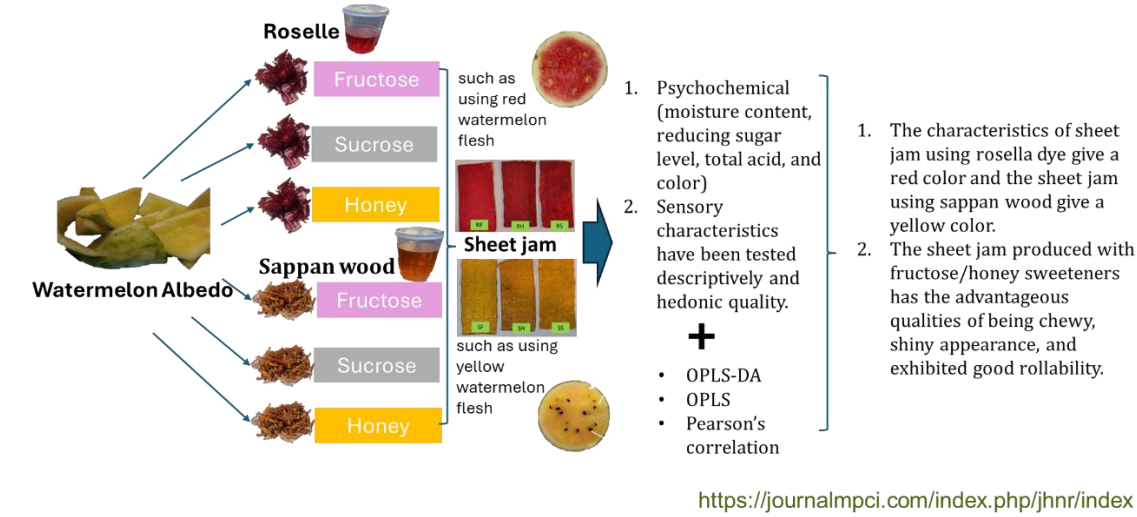
GRAPHICAL ABSTRACT

Imitation watermelon sheet jam made from watermelon albedo with natural coloring from roselle petals (*Hibiscus sabdariffa L*) and sappan wood (*Caesalpinia sappan L*)



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INTRODUCTION

Sheet jam is a semi-solid jam that has been concentrated into a solid or sheet form (1). Pectin, acid, and sugar are the main components of jam, and gelatine is one of the components that can be utilized to form it into sheets. Watermelon's albedo naturally contains pectin at 21.03% (2), while the albedo is included in the 30% of the unused area of the watermelon (3), and contributes 54% of the total dissolved solids in watermelon juice production (4) as well as having the characteristic of sour taste (5). This promotes the albedo of watermelon as a raw ingredient for sheet jam, but to get the appearance (color) of watermelon, sugar must be added to assist the gel and sweet taste formation.

Granulated sugar, often known as sucrose, is a type of sugar that is frequently used in food processing. The gel made from gelatine hydrocolloid is strengthened by the addition of sugar in the form of fructose and sucrose (6). Honey, especially *kelulut* honey (stingless bee honey), naturally contains fructose. *Kelulut* honey comes from stingless bees, which have a higher composition of glucose, fructose, sucrose, and total acid compared to forest honey from stinging bees (7); hence, it has a unique taste, namely sweet and sour. Its use in a 1:1 sucrose formulation to make pineapple jelly candy has been shown to substitute the need of citric acid and act as a doctoring agent or crystallization prevention, in contrast with the use of sucrose sweetener, which results in jelly candy with a crystallized surface (8). Another formulation, sucrose, the stingless bee honey (*Kelulut)*, and stevia in a 4:3:1 ratio in jelly candy products, contributes to increase the vitamin C levels while decreasing calorie availability as compared to sucrose sweetener (9).

Roselle flowers (*Hibiscus Sabdariffa* L) and sappan wood/s*secang* (*Caesalpinia Sappan* L) are the natural dyes with the hue of watermelon flesh. The roselle flowers provide a red color that is caused by the anthocyanin content (10). Meanwhile, sappan wood contains brazilin color pigment (11) that provides yellow color at pH 3-6, orange at pH 7, and red in alkaline conditions (12). In addition to being dyes, the roselle flowers and sappan wood contain antioxidant and antihyperglycemic characteristics (13,14). As a result, it offers several benefits, including improved physical appearance and health.

This research aims to obtain the differences between psychochemical and sensory characteristics of imitation watermelon sheet jam with watermelon albedo on the use of natural dyes (roselle petals and sappan wood/*secang*), and the different sweetener formulations (sucrose, sucrose-fructose, and sucrose-honey). Water content, reducing sugar, total acid, and color are the physicochemical properties measured (L, Hue, and C). Color, aroma, texture, taste, and overall preference are generally used to describe the sensory characteristics. Differences in physicochemical and sensory characteristics are examined using multivariate analysis, as well as the main characteristics that determine preferences or hedonic quality. The multivariate analysis using principal component analysis (PCA) and orthogonal partial least squares discriminant analysis (OPLS-DA) has concluded that the bitter taste diminishes preference when compared

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to the astringent flavor of *karamunting* leaves, a herbal tea product (15). Departing from the above explanation, multivariate analysis can be a novelty in research related to a sheet jam, specifically to obtain sensory attributes that determine the level of preference.

METHODS

Producing Roselle And Sappan Wood Extracts

Fresh roselle petals were boiled for 5 minutes at 92±1°C with a water:roselle ratio of 10:1 to produce the roselle extract; and then it was filtered (total dissolved solids were 0.3±0.1%). After boiling the *secang* for 5 minutes at 92±1°C with a water:secang ratio of 40:1, the sappan wood/*secang* extract was filtered (total dissolved solids were 0.45+0.15%).

Producing Sheet Jam

Roselle and sappan wood (*secang*) extracts were used as natural dyes in this research, and the watermelon albedo material was the main source of total dissolved solids in the sheet jam. Table 1 revealed the sheet jam formulation that was utilized.

Table 1. Sheet jam formulation (in *g* units)

Material	RF	RH	RS	SF	SH	SS
Watermelon Albedo	100	100	100	100	100	100
Roselle Extract	200	200	200	-	-	-
*Secang/*Sappan Wood Extract	-	-	-	200	200	200
Sucrose	68	68	136	68	68	136
Kelulut Honey (Stingless Bee Honey)	51	-	-	51	-	-
Fructose	-	51	-	-	51	-
Stevia	0.17	0.17		0.17	0.17	
Gelatine	6	6	6	6	6	6
Citric acid	0.9	-	0.9	0.9	-	0.9

Description: The first letter of the treatment code is R for Roselle and S for *Secang/*Sappan wood, the second letter F for fructose, H for honey, and S for sucrose.

The producing of sheet jam was done by heating the mixture of ingredients (except the citric acid) at a temperature of 83±1°C for 3 minutes and those were added with citric acid (except for the treatments with RH and SH honey sweeteners); furthermore, these were molded in a 25 x 30 x 1 cm silicone container and left for one hour to solidify. The sheet jam was cut off with a size of 10x10cm and dried with a food dehydrator for 10 hours at a temperature of 55°C (16). The sheet jam was analyzed on the 7th day after the drying (the aging period).

Physicochemical Analysis

The results of the physicochemical study included moisture content, reducing sugar, total acid, and color. The analysis of moisture content (AOAC 925.10) was determined by drying the sample in an oven for a certain period (temperature of 105°C), the sample weight was weighed before and after drying, and the weight difference was used to compute the moisture content as a percentage of dry weight. The reducing sugar content was calculated using the principle of reducing sugar by converting the Luff Schoorl solution to CuO_2, then the levels were determined by titration using sodium thiosulfate solution (SNI 3547-2-2008 on soft confectionery). The total acid was measured by using the volumetric method (7). The color analysis was done by using colorimeter to gain the L value (dark to bright), a* (red to green), and b* (yellow to blue); moreover, the color determination was determined by using the °Hue value and the color brightness of C* was calculated using the formulation of $tan^{-1}\frac{bx}{ax}$ and $\sqrt{a*^2+ b*^2}$ (17,18). The red °Hue value was 328 to 32, while the yellow color was 67 to 99 (18). Four repetitions were carried out in this experiment.

Sensory Characteristics

Sensory characteristic was completed by using descriptive sensory analysis (19). Thirty food science and technology students who had completed the sensory course served as the panelists. Rollability, clear appearance, red/yellow color density, fruity and herbal aromas, sweetness, and chewy texture were

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the sensory characteristics that were investigated. Descriptive measures of sensory attributes were developed, and five scales were used to assess each attribute's level of preference.

Data Analysis

Data analysis was done by means of multivariate analysis with the SIMCA 16 (Sartorius Stedium Data Analytics AB, Sweden) in Pareto scaling (15). The analysis of product characteristic data began with the PCA to generate sample groupings based on sensory attributes, which were subsequently refined using OPLS-DA analysis to determine the unique characteristics of each product. The OPLS-DA analysis was able to separate and produce a perfect distinguishing field between classes (Bylesjo et al., 2006). The analysis was continued with OPLS to link the product's physicochemical and sensory characteristics (variable x) with the hedonic score (variable y), resulting in physicochemical and sensory characteristics that corresponded with the level of preferences. The PCA, OPLS-DA, and OPLS models should have the score of Q2>0.4. The analysis of OPLS-DA and OPLS was validated by using *Cross-Validation Analysis of Variance* or CV-ANOVA ($p<0.05$); moreover, it was required to satisfy the permutation test requirements. The permutation test should indicate the scores of R2 and Q2, which were always lower than the original model (Tunnisa et al., 2022).

RESULTS

Physicochemical Analysis

The raw materials used in this sheet jam research were watermelon albedo with natural dyes (roselle extract and span wood/*secang*) to create a watermelon-like color. Producing sucrose (granulated sugar) with readily available doctoring agents, including simple sugars or monosaccharides (such as *kelulut* honey), is an option for creating inexpensive, non-crystallizing sheet jam. *Kelulut* honey has the advantage of having a characteristic taste that is both sweet and sour (7). The high price of *kelulut* necessitates the search for alternatives to replace it with other comparable materials, specifically fructose. Physicochemical measurements that have been carried out on sheet jam are: moisture content, reducing sugar, total acid, color in the L value, ^{o}Hue, and C*. Table 2 depicts the results of the physicochemical measurements.

Table 2. Physicochemical characteristics of sheet jam

Treatments	Moisture Content	Reducing Sugar	Total Acid	^{o}Hue	L	C*
RF	16.45±1.02^{cd}	55.74±0.72^{e}	28.95±0.62^{b}	2.82±1.33^{a}	19.95±0.75^{bc}	4.92±0.06^{c}
RM	16.85±0.35^{d}	54.53±0.38^{d}	29.14±0.75^{b}	9.77±1.71^{b}	19.43±0.30^{b}	4.11±0.03^{b}
RS	13.83±0.80^{a}	53.01±0.67^{c}	28.99±0.76^{b}	16.22±1.31^{c}	16.33±0.52^{a}	3.41±0.09^{a}
SF	15.58±0.45^{bc}	33.14±0.34^{b}	17.27±0.57^{a}	83.26±0.63^{f}	25.58±0.43^{e}	6.25±0.06^{e}
SM	15.84±0.68^{bcd}	32.90±0.29^{b}	17.12±0.81^{a}	68.13±1.30^{d}	21.80±0.59^{cd}	6.18±0.03^{e}
SS	14.84±0.81^{ab}	24.42±0.49^{a}	17.93±0.20^{a}	71.17±0.86^{e}	22.83±0.59^{d}	5.57±0.08^{d}

Description: Different alphabets after the numbers (data) indicate differences ($P<0.05$) between treatments. Symbols for treatments codes: the first letter is R for Roselle and S for Secang/Sappan Wood, the second letter is F for fructose, H for honey, and S for sucrose.

The physicochemical characteristics of moisture content, reducing sugar, total acid, and color are all impacted by the sweetener-dyed sheet jam formulation (Table 1) with the L value, ^{o}Hue, and C* (Table 2). The moisture content of sheet jam is in the range of 13.83 – 16.85%. The reducing sugar of sheet jam is in the range of 24.42 – 55.74%. The color of the sheet jam has an ^{o}Hue value, namely 2.82 to 16.22 by means of roselle dyes, while the *secang* dye is 68.13 to 83.26. The L value of sheet jam is 16.33 to 25.58.

Sensory Characteristics

Figure 1 represents the sensory characteristics of watermelon albedo sheet jam in different colorant-sweetener combinations. The sweetener-dyed sheet jam had a significant effect ($P<0.05$) on all sensory characteristics examined (Figure 1a). The sheet jam using sucrose sweeteners has different

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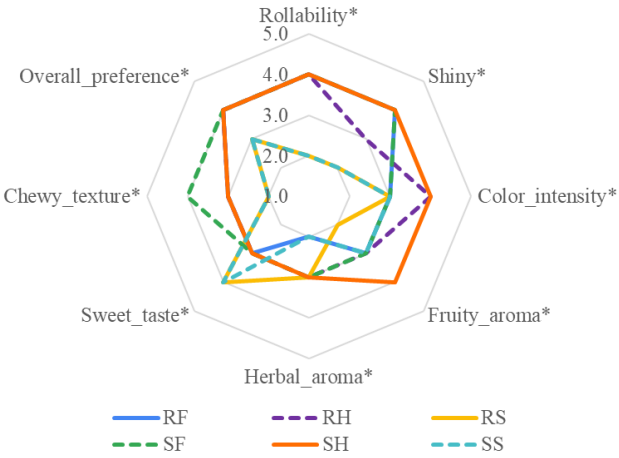
sensory characteristics with fructose and sucrose, specifically in the ease of rolling, shiny appearance, chewy texture, and the low overall preferences, while the taste is sweeter.



*indicates a significant effect (P<0.05)

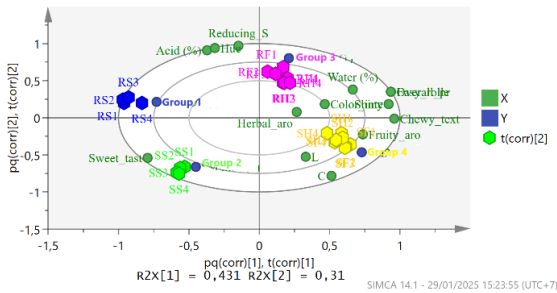
(a)

(b)

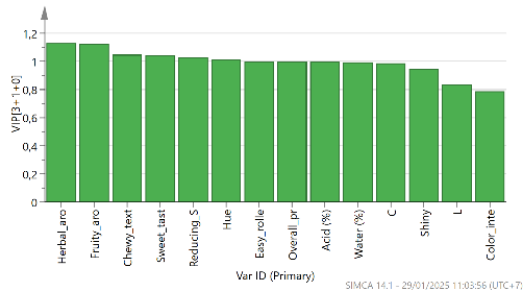
Figure 1. Watermelon albedo sheet jam, (a) sensory profile and (b) appearance. The first letter of the sample code indicates the use of natural dyes of roselle extract (R) and sappan wood extract (S), the second letter indicates the use of fructose sweeteners (F), stingless bee honey (H)/*kelulut*, and sucrose (S).

Physicochemical and Sensory Characterization of Sheet Jam

The results of multivariate analysis on the sheet jam using colorant-sweetener formulation indicate that there are 4 groups (Figure 2a). The sheet jam with sucrose sweetener is used in group 1 (blue) with roselle dye, and group 2 (green) with sappan wood dye. Group 3 (pink) comprises two treatments with roselle dye containing fructose and honey sweeteners, while group 4 (yellow) contains two treatments with sappan wood dye. Treatments in the same group have identical physicochemical and sensory characteristics, but treatments in different groups demonstrate the opposite. The differences in the main physicochemical and sensory characteristics of sheet jam are shown in the characteristics with *variable importance in the projection* (VIP) values > 1 (Figure 2b). Those characteristics are herbal aroma, fruit aroma, chewy texture, sweet taste, reducing sugar, the value of °Hue, the ease of rolling, overall preferences, and total acid (Figure 2b).



(a)



(b)

Figure 2. Treatment grouping based on physicochemical and sensory characteristics with OPLS-DA at R2X 0.941 and Q2 0.957, (a) Biplot and (b) VIP. The first letter of the sample code indicates the use of natural dyes of roselle extract (R) and sappan wood extract (S), the second letter indicates the use of fructose sweeteners (F), *kelulut* honey (stingless bee honey) (H), and sucrose (S).

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The Correlation Between Psychochemical and Sensory Characteristics (x) with Overall Preferences (y)

The results of multivariate analysis on the sheet jam based on the psychochemical characteristic that was correlated with the overall preferences, demonstrated the division into two sizable groups, of which group were group 1-2 and group 3-4 (Figure 3a). The treatments using roselle-sucrose and *secang*-sucrose had different level of preference or were lower than the roselle-fructose/honey and *secang*-fructose/honey treatments. The characteristics that determine the level of preference for sheet jam are indicated by the characteristics that have a value of *variable importance in the projection* (VIP) > 1 (Figure 3b). These characteristics cover up the ease of rolling, sweetness, shiny appearance, chewy texture, and moisture content (Figure 3b).

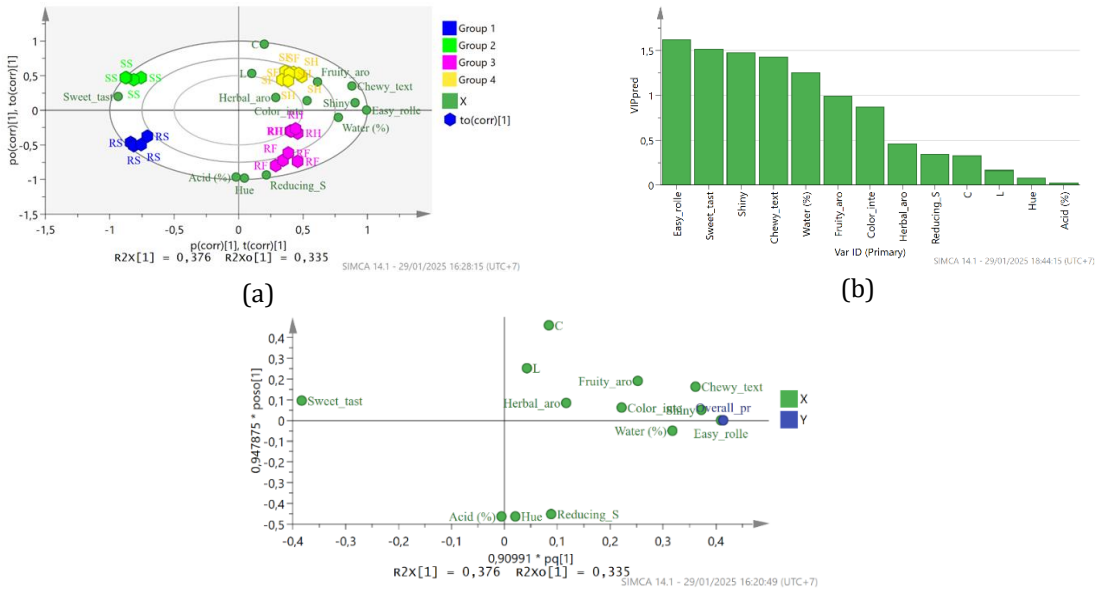

Figure 3. Biplot of treatment grouping based on correlation of physicochemical and sensory characteristics x with overall preference of y using OPLS at R^2X 0.711 and Q2 0.987 (a), VIP (b), and loading plot showing physicochemical and sensory characteristics x with overall preference of y using the OPLS at R^2X 0.711 and Q^2 0.987 (c). The first letter of the sample code indicates the use of natural dyes of roselle extract (R) and sappan wood extract (S), the second letter indicates the use of fructose sweeteners (F), *kelulut* honey (H), and sucrose (S).

The Pearson correlation data further illustrate the reduction of the physicochemical and sensory characteristics that affect overall preference (Figure 4). These characteristics are derived based on the r value, which is greater than 0.8 (r > 0.8), indicating a very high correlation (20). Overall, these characteristics are sensory characteristics, viz. the ease of rolling (r 1.00000), sweetness (r -0.92582), shiny appearance (r 0.91915), and chewy texture (r 0.88641) (Figure 4).

	Water (%)	Reducing_Sugar (%)	Acid (%)	L	Hue	C	Easy_rolled	Shiny	Color_intensity	Fruity_aroma	Herbal_aroma	Sweet_taste	Chewy_texture	Overall_preference
Water (%)	1	0.21550	0.12613	0.17071	0.19214	0.02109	0.73503	0.56980	0.46693	0.65492	-0.04610	-0.58778	0.50324	0.73503
Reducing_Sugar (%)		1	0.95669	-0.51917	0.94956	-0.82430	0.20215	0.03054	0.08068	-0.38340	0.12496	-0.43662	-0.12210	0.20215
Acid (%)			1	-0.51390	0.97817	-0.89996	-0.02760	-0.21728	-0.01259	-0.44194	-0.02502	-0.18158	-0.37065	-0.02760
L				1	-0.51877	0.43203	0.11548	0.19340	-0.20351	0.51485	-0.27924	0.10867	0.26666	0.11548
Hue					1	-0.91613	0.03876	-0.14079	0.06349	-0.34927	-0.10532	-0.21828	-0.35276	0.03876
C						1	0.19824	0.25579	0.30023	0.43195	0.37873	-0.03395	0.52450	0.19824
Easy_rolled							1	0.91915	0.50000	0.63246	0.25000	-0.92582	0.88641	1.00000
Shiny								1	0.26261	0.58132	0.13131	-0.85096	0.90996	0.91915
Color_intensity									1	0.31623	0.50000	-0.46291	0.32233	0.50000
Fruity_aroma										1	-0.31623	-0.29277	0.56061	0.63246
Herbal_aroma											1	-0.46291	0.40291	0.25000
Sweet_taste												1	-0.82065	-0.92582
Chewy_texture													1	0.88641
Overall_preference														1

Figure 4. Pearson correlation between psychochemical and sensory characteristics with the overall preferences.

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DISCUSSION

Physicochemical Analysis

Formulations with sucrose sweeteners often include less water than those with fructose and honey sweeteners, and they also tend to have a lower moisture content (Table 2). Since fructose and honey have larger moisture contents than sucrose, sheet jam with these two sugars has a high moisture content. Thus, with the same temperature and heating time, it is expected to create the same reduction in the moisture content of sheet jam. The moisture content of *Kelulut* honey is 30$\pm$2% (7) and a liquid fructose is 20% (packaging details) while the sucrose or granulated sugar is about 0.61% (21). The moisture content of a product that has been dried will decrease along with the length of drying time (22).

The formulation using the sucrose sweeteners tends to have the reducing sugar that is lower than the formulation using fructose and honey. This is because sucrose has a lower reducing sugar content than honey or fructose. Sucrose or granulated sugar contains the reducing sugar of 1.24% (21). Meanwhile, the *Keluluit* honey contains the reducing sugar of 60% (7) and a liquid fructose of 80% (packaging details). The reducing sugar of sheet jam using the formulation of sucrose sweeteners from roselle extract is higher than the extract of *secang* or sappan wood. This is due to the acid components of Roselle, which is also shown by the high total acid content of jam sheets with roselle compared to sappan wood (Table 2). The Roselle extract has a pH of 3.4 (23), while the *secang* is 6,82 (24). The roselle has a sour taste since it contains citric acid and malic acid (25). The pH condition of roselle extract which is sourer than sappan wood, also causes the reducing sugar content in sheet jam with roselle dye to be higher than by using sappan wood dye. This is because sucrose is hydrolyzed into reducing sugars (glucose and fructose) under both heating and acidic conditions. Sucrose inversion arises under acidic circumstances, when sucrose is hydrolyzed to provide one D-glucose and one D-fructose (26).

Based on the Hue value in the Table 2, it shows that the sheet jam using roselle dyes has red color, whereas the *secang* is yellow. This can be proven from the real appearance of the resulting sheet jam (Figure 1b). The red ^{o}Hue value is in the range of 328 to 32, while the yellow is 67 to 99 (18). The red color of roselle is caused by the anthocyanin contents (25); meanwhile the yellow color of *secang* comes from brazilin (27). Brazilin contained in *secang* / sappan wood at pH $\leq$ 4 will provide the yellow color, while at the pH 6, it is orange and at the pH $\geq$ 8 is pink to red (28,29). The color change is induced by the hydroxyl group of brazilin transforming into a protonated in acidic conditions and deprotonated in base conditions. Other research investigations have found that brazilin is more resistant to heat in acidic circumstances (yellow color) than under neutral to basic pH (30).

The sheet jam using sucrose sweeteners tends to have a lower L value, particularly when it is compared to the sheet jam with fructose sweeteners. This implies that sheet jam using sucrose sweetener has a lower brightness level compared to fructose (glucose:fructose 57%:43%). This is because the mixture of sucrose molecules caused the sheet jam made with sucrose sweetener to crystallize on the seventh day after drying. Compared to glucose and corn syrup, fructose is more efficient at inhibiting sucrose crystallization (DE 37.5). Previous study showed that there is no crystallization on 84th day on the ration of sucrose:fructose (85:15), sucrose:glucose (60:40), and sucrose:corn syrup (80:20); furthermore, crystallization occurs on 7th day at lower quantities of simple sugars because these sugars decrease the amorphous sugar matrix's molecular mobility and can interact with sucrose by forming hydrogen bonds, which alters translational and rotational diffusion (31). In order to create sheet jam that stays chewy and shining, crystal formation must be inhibited. In candy products, this is also done to create hard candy that will not lose its brightness or shine (32). The sheet jam using sucrose sweetener has a lower C* value than sheet jam with fructose and honey. This suggests that sheet jam made primarily with sucrose sugar has a weaker red or yellow color. This is also believed to be caused by the crystallization of sucrose, which reduces the intensity of the color. In chocolate products, crystallization results in a reduction of brightness (L) and chroma value (C*) (33).

Sensory Characteristics

The low of sensory characteristics (rollability, shiny appearance, and chewy texture) are caused by the crystallization of sheet jam surface with sucrose sweetener. Crystal formation makes the sheet jam

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more fragile, causing it to shatter and become harder to roll. The creation of crystals also changes the texture from chewy to crispy, similar to biting chips, which is hypothesized to be owing to the formation of holes between the sucrose crystals. Sucrose crystals develop microscopically, allowing for holes between them (31). The lower L color measurement results (Table 2) in sheet jam with sucrose sweetener, as compared to sweeteners encompassing fructose and honey, support the decrease in glossy appearance. The appearance of the resulting sheet jam is noticeable, with sucrose sweetener producing a duller or more reminiscent appearance due to the formation of sucrose crystals, while those consisting of fructose and honey sweeteners are shinier (Figure 1b).

The sheet jam taste using sucrose sweetener is sweeter than the fructose and honey (Figure 1a), this is due to the low of moisture content in sheet jam with sucrose sweetener (Table 2). The low of moisture content creates a thicker condition, so it has a sweet taste. Meanwhile, the sweetness level of honey is determined by the composition of glucose and fructose contained, it is known that fructose is sweeter than glucose when compared to sucrose (34). The *kelulut* honey has higher glucose composition than fructose (7); thus, the sweetness level is lower than the sucrose.

The Aroma (fruit and herbal) of sheet jam is affected by the treatment of colorant-sweetener formulations with patterns that are difficult to explain. The results indicate that the sheet jam using natural dyes of roselle and *secang* has herbal aroma, yet intensity is not strong. Other studies identify the roselle extract that contains volatile components, of which components are groups of ketone compounds, aldehydes, terpenes, alcohols, and esters (35). Aside from that, sappan wood extract contains 38 components, including volatile oils (36). It is believed that the compound contributes to the fruity or herbal aroma of sheet jam. It is also believed that stingless bee honey (*kelulut)* and watermelon albedo contribute to the fruity aroma of sheet jam. Another study signifies that watermelon albedo contains 15% of volatile compounds from volatile compounds of fruit flesh. More than 80% of the compound is made up of aldehyde and alcohol components, which give it a fresh, green aroma and are similar to cucumber. Furthermore, the watermelon albedo is superior in terms of citrulline and arginine content (37). The stingless bee honey (*kelulut)* comes from *Trigona sp*, in which it has fruity aroma (38).

Physicochemical and Sensory Characterization of Sheet Jam

The multivariate analysis indicates that the formulation of natural dyes in sheet jam presents different values of ^{o}Hue, reducing sugar content, and total acid (Figure 2a). This is consistent with the measurement of the ^{o}Hue value, which ranges from 2.82 to 16.22 (red) with Roselle dye and 68.13 to 83.26 (yellow) with Sappan wood dye (Table 2). The red color from roselle is caused by the anthocyanin content (25), while the yellow color from sappan wood/*secang* is caused by brazilin compound (27). Roselle contains organic acids such as citric and malic acids (25), so the total acid content in roselle sheet jam is high and this is also the cause of the high reducing sugar content. Organic acids can trigger the breakdown of sucrose into reducing sugars (glucose and fructose) by providing H^{+}, this also occurs in the manufacture of coconut sugar in acidic conditions producing lower sucrose levels (26). Therefore, in the case of the roselle sheet jam, the reducing sugar produced is higher since the sucrose will be hydrolyzed not only by the heating process but also by the acidic action. The organoleptic test showed that the panelists preferred the keribang tubers jam with a CMC concentration of 0.5% and a heating time of 15 minutes in terms of color and texture (39).

Sweetness formulation in sheet jam provides different sweetness level, herbal aroma, fruity aroma, ease of rolling, and the overall preferences (Figure 2a). Sucrose sweeteners tend to have a greater sweet taste than fructose or honey. This is due to sucrose's high or low moisture content. Sweetener formulations containing fructose or honey produce sheet jam with more elasticity, ease of rolling, and overall preference than sucrose sweeteners. This is because fructose and honey can either function as a doctoring agent or inhibit the crystallization of sucrose by diffusing to the surface and preventing the formation of crystals by sucrose molecules attaching to one another (31). This beneficial phenomenon makes sheet jam with honey or fructose sweeteners easier to roll and gives it a chewy texture.

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The Correlation Between Psychochemical and Sensory Characteristics (x) with Overall Preferences (y)

This research has shown that the sweeteners including fructose and honey have an additional benefit of providing the sensory characteristics of rollability sheet jam, shiny appearance, chewy texture. These characteristics support the preference level of sheet jam. This is consistent with earlier studies that demonstrate the chewy texture and rollability of sheet jam (40,41).

Sensory characteristics of sweetness (r -0.92582) have negative correlation with the preference level, which means that the higher the level of sweetness, the lower the preference (Figure 4). Meanwhile, other sensory characteristics have positive correlation with the preference level. This is also observed in prior studies, which reveal a negative correlation between sweetness and preference level (42). Further researches related to the reason of sweetness can influence the preferences, in which it is shown by the r values between sweetness and the rollability (r -0.9582), shiny appearance (r -0.85096), chewy texture (r -0.82065). As previously mentioned, the use of sucrose sweetener without fructose/honey results in the formation of a layer of crystals on the surface, causing the sheet jam were low rollability, less shiny appearance, and not chewy.

CONCLUSION

The characteristics of sheet jam using roselle dye give a red color appearance with a higher reducing sugar and total acid content compared to sappan wood dye. The sheet jam characteristics using sucrose sweetener have a sweeter taste compared to the sheet jam containing fructose fructose/honey. The sheet jam produced with fructose/honey sweeteners has the advantageous qualities of being chewy, shiny, and rollability. The chewy texture, shiny appearance, and rollability are the characteristics of sheet jam that are positively correlated with preference, whereas sweetness is negatively correlated.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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