Effect of Sugar-Pectin-Citric Acid Pre-Commercialization Formulation on the Physicochemical, Sensory, and Shelf-Life Properties of *Musa cavendish* Banana Jam

(Kesan Formulasi Pra-Pengkomersialan Gula-Pektin-Asid Sitrik terhadap Fizikokimia, Deria, dan Jangka Hayat Jem Pisang *Musa cavendish*)

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ABSTRACT

Cavendish banana is the second most cultivated species in Malaysia due to its high potassium and vitamin B6 content. However, there has been little commercialisation of Cavendish banana in jam making to date because of its unappealing physical characteristics and unsavoury taste. In the present study, response surface methodology was used to determine the optimum quantity of sugar (175-275 g)-pectin (3-7 g)-citric acid (150-234 mL) (SPC) on water activity, °Brix, colour analysis, pH, total titratable acidity (TTA), and sensory attributes of formulated banana jams. The amount of sugar-pectin-citric acid was found to have an effect on the TTA and pH of the banana jams. Conversely, water activity and °Brix were only affected by the amount of sugar. The lightness, L* of the banana jams was influenced by the quantity of pectin and the volume of citric acid added. Sensory analysis using 30 panellists showed that there were changes in the colour, taste, aroma, texture, and overall acceptability of banana jam depending on the amount of sugar used. In a shelf life study, banana jams stored at 4 °C were found to have a longer shelf life compared to those stored at 25 °C. Overall, the optimal formulation for a high-quality banana jam was 281.79 g of sugar, 4.13 g of pectin, and 264.66 mL of citric acid. This study constitutes the first report on the potential pre-commercialisation formulation for Cavendish banana jam production.

Keywords: Cavendish banana; jam; pectin; response surface methodology; sensory evaluation; shelf life

ABSTRAK

Pisang Cavendish ialah spesies pisang kedua terbanyak ditanam di Malaysia disebabkan kandungannya yang tinggi potasium dan vitamin B6. Namun, usaha pengkomersialan pisang ini terbatas disebabkan oleh rupa dan rasanya yang kurang menarik dan sedap. Kajian ini menggunakan kaedah gerak balas permukaan untuk menentukan nilai optimum kandungan gula (175-275 g)-pektin (3-7 g)-asid sitrik (150-234 mL) (SPC) terhadap aktiviti air, °Brix, analisis warna, pH, jumlah keasidan yang dapat dititrat (TTA) dan deria rasa bagi jem pisang yang dihasilkan. Kandungan gula-pektin-asid sitrik didapati mempunyai impak terhadap TTA dan pH jem pisang. Sebaliknya, aktiviti air dan °Brix hanya dipengaruhi oleh jumlah kandungan gula. Kepekatan warna, L* jem pisang ditentukan oleh jumlah pektin dan asid sitrik yang digunakan. Analisis deria rasa jem pisang dilakukan oleh 30 orang panelis dan mendapati perubahan dalam warna, rasa, aroma, tekstur dan penerimaan keseluruhan jem pisang bergantung kepada jumlah gula yang digunakan. Jem pisang yang disimpan pada suhu 4 °C dilihat mempunyai jangka hayat yang lebih lama berbanding dengan jem pisang yang disimpan pada suhu 25 °C. Secara kesimpulannya, kadar optimum untuk menghasilkan jem pisang yang berkualiti tinggi adalah 281.79 g gula, 4.13 g pektin dan 264.66 mL asid sitrik. Kajian ini merupakan laporan pertama mengenai potensi formulasi pra-pengkomersialan untuk pengeluaran jem pisang Cavendish.

Kata kunci: Deria rasa; jangka hayat; jem; kaedah gerak balas permukaan; pektin; pisang Cavendish

INTRODUCTION

Banana is a fruit that grows extensively in the tropics and in many sub-tropical countries (Thompson et al. 2019). The Cavendish subgroup is the highly cultivated and requested worldwide (Lobo & Rojas 2020). Banana (*Musa* sp., family Musaceae) is the second largest produced fruit and it has a total of 16% of the total fruit production globally (Pathak et al. 2017). This species of banana weighs 25-40

kg and has 15-25 combs per bunch. Each fruit measures 9-33 cm in length and 2.5-7.0 cm in diameter (Novitalia et al. 2020). The most apparent change in bananas during ripening is their peel color. The content of chlorophyll content reduced or absent in ripe fruit (Lobo & Rojas 2020). The pulp is white, smooth, and soft textured with a sweet taste. Cavendish banana is usually eaten raw or made into delicacies such as desserts and jams (Ding et al. 2015).

Cavendish banana is highly nutritious. Banana is a highly nutritious fruit with high source of phytochemicals, unsaturated fatty acids and sterols and a medium-sized banana consists of 6 g of fibre (Netshiheni et al. 2019). It is very rich source of carbohydrates, minerals (potassium and calcium) as well as vitamins (A, B1, B2, and C) and provides significant amount of energy (100 Cal/100 g) to the body (Ahmed et al. 2017a). Besides that, bananas contain various antioxidant compounds such as ascorbic acid, tocopherol, beta carotene, phenolic groups, dopamine and gallocatechin (Shian & Abdullah 2012). According to Soradech et al. (2017), it consists of high content up to 15% of vitamin C. Furthermore, there are also a high quantity of tryptophan, calcium, magnesium, and vitamin B6 in banana (Bu et al. 2020). Implementing a diet rich in fiber and potassium can control high blood pressure, hypertension, and its complications (Ajeigbe et al. 2020). Tryptophan found in banana increases serotonin synthesis and contributes to many behavioral consequences of increased serotonergic activity includes elevate mood in people (Bu et al. 2020). However, the chemical composition of banana changes depending on the maturation stage. As the bananas mature and ripen, starch content decreases because approximately 80% of starch transformed to soluble sugars such as glucose, fructose and sucrose which increases the soluble sugar to 19% (Palijama et al. 2020).

Banana is highly perishable and easily deteriorates, especially after ripening. After harvesting, banana loses its water content, rendering it prone to shrivelling, weight loss, and attack by insects and decay-causing organisms (Serrano & Rolle 2018). Palijama et al. (2017), stated that fruit maturation process causes significant changes in chemical and biochemical that cause rapid maturation and ripening. During the maturation process occurs of changes in banana that causes changes in color, texture, taste, and other chemical differences such as differences in acidity, carbohydrates, pectin, protopectin, tannin, and volatile contents (Palijama et al. 2017). According to Chen et al. (2020), dramatic softening and a short shelf life can be observed after harvesting of banana. In addition, Toma et al. (2018) mentioned that the peel colour of banana

changes from green to yellow, decrease in firmness and followed by fruit softening as well as starch is converted into sugar. An average of 20-25% of the harvested banana fruits are decayed by different fungi during postharvest handling and about 1.6 million bananas are discarded daily (Idris et al. 2015).

The earlier mentioned limitations can be mitigated by proper postharvest handling of bananas and by commercialising banana into processed food products such as jam, jellies, and chips. According to the Food and Agriculture Organization of the United Nations (FAO), the banana trade reached up to 114 million tonnes in 2017, with Asia, Latin America, and Africa being the prime producers. Banana is also a cheap product, ranging from USD 0.90-1.00/kg (FAO 2016) in trading market. In Africa, 70 million citizens depend on banana and plantain for 25% of their energy intake. Ripe bananas undergo industrial processing to produce various products including puree, juice, and jam (Shandilya & Siddiq 2020). In order to produce high-quality jam, the processed fruit must be ripe, have no signs of rotting, and contain sufficient pectin and acid (Dahlan 2020). Processing banana into food products eliminates food wastage, increases food diversification among consumers, improves shelf life, and provides food security. Furthermore, processing may improve market efficiency and generate employment, especially for local and small producers (Singh et al. 2018).

Jams have historically been prepared to preserve perishable fruits for consumption during the off-season. Apart from their pleasant taste, jams have a favourable nutrient profile, such as high levels of sugar, fibre, minerals, and amino acids and an absence of fat and cholesterol (Bekele et al. 2020). Jams are typically eaten on a daily basis with bread at breakfast or are used in desserts such as cakes and pastries. Jam is a semi-solid food product, obtained upon cooking of fruits or vegetables pulp with sugar, citric acid and pectin as well as other ingredients to produce a reasonable consistency (Ahmed et al. 2017b). According to Aziz et al. (2020), the heating process in jam production decreases the moisture content and sugar act as a preservative, sweetener, and gives a better consistency and texture to the end product and also helps in gel formation.

The preparation of jam is influenced by multiple factors such as the quality of the fruit and levels of pectin, sugar, pH, and total soluble solids (Aziz et al. 2020). Siddiqui et al. (2020) studied that highest amount of pectin can also be obtained from slightly under ripe bananas which increasing pectin content during development and decreasing pectin content during ripening. In jam

production where both hydrophilic and hydrophobic interactions take place, pectin acts as a gelling agent and food hydrocolloid (Shinwari & Rao 2020). Sugar enhances the taste, flavor, colour, and the texture of processed fruit products (Okine 2017). Okine (2017), also stated that the high amount of sugar prevents the water from the microorganisms which causes the microorganisms dehydrated and incapable to prevent spoilage of jam. A sufficient amount of acid is required for gel formation (Joardder & Masud 2019).

In the present study, *Musa cavendish* banana pulps were formulated as banana jams. Response surface methodology (RSM) was employed to determine the optimal levels of sugar and pectin and volume of citric acid for jam production without compromising the physicochemical properties, sensory attributes, and shelf life of the jam. As Cavendish banana is rich in nutritional content, this approach allows the plant to be utilised to its optimum potential and benefits the growth of local industry.

MATERIALS AND METHODS

CAVENDISH BANANA PULPS PREPARATION

Cavendish bananas (*Musa cavendish*) were purchased from the Heromart, Sri Serdang, Selangor, Malaysia, and were washed and peeled to isolate the pulps (460 g). The pulp was sliced into small pieces and ground with water (100 mL) into a mash. Next, the mash was boiled at 100 °C , and mixed with sugar (175-275 g) and pectin (3-7 g). When the mixture reached 60 °C, citric acid was added (150-234 mL, pH 3.08) and the mixture was stirred continuously until it had gelled. The jam was cooled, packed into plastic containers, and stored at either 4 °C (Tin et al. 2015) or 25 °C in a growth chamber (GC-500, Protech, Malaysia). A total of 16 banana jam samples were prepared. The samples subsequently underwent physicochemical and modified sensory analyses (Wan-Mohtar et al. 2018), optimised using RSM according to Sohedein et al. (2020), to determine the optimal amount of sugar and pectin and volume of citric acid for the jam formulation. All analyses were performed in triplicate.

PHYSICOCHEMICAL ANALYSIS
DETERMINATION OF TOTAL TITRATABLE ACIDITY (TTA)

Samples of jam (6 g) were mixed with distilled water (50 mL) and stirred for 2 min until the solution was homogenous. Phenolphthalein (3 drops) was then added to the solution (10 mL) and titrated with NaOH (0.1 M) until a pale pink colour was obtained. The volume of titrated NaOH was recorded. The method used was followed from Nguyen et al. (2017):

Percentage of malic acid (%) =

$$\frac{(\text{volume of titrated NaOH} \times 0.1\text{M NaOH} \times 0.067\ \times 100)}{\text{weight of samples (g)}} \quad (1)$$

pH DETERMINATION

The pH of banana jam was measured according to Ngoh Newilah et al. (2018). The pH of banana jam was measured according to 5 g of each produced jam samples were diluted with 50 mL distilled water to make a 10% solution. The pH values of the filtrate were measured using a digital pH meter (Eutech pH 700, Singapore).

COLOUR ANALYSIS

Samples of jam were analysed for colour using a chromameter (Konica Minolta R-300) and CIELAB system (illuminator = D65, angle of observation = 10°). The lightness (L*) of the jams was determined using measurements from three different areas of the samples.

TOTAL SOLUBLE SOLID (BRIX) AND WATER ACTIVITY ANALYSES

The total soluble solid content of the jams was measured using a refractometer (Abbe Atago 89553 refractometer) (Brandao et al. 2018). A small sample of jam was taken and cooled to 20 °C. The jam was then dropped into the prism and held near a source of light. The results were recorded and expressed as degree of brix (°Brix). Water activity was determined using a Unit 3TE Aqualab (Decagon Devices Inc., WA, USA). The jams were tested for 5 min and the results were recorded.

SENSORY EVALUATION

Sensory testing was carried out by 30 panellists from the Faculty of Food Science, Universiti Putra Malaysia, Serdang, Selangor as described previously by Nurhanan and Aishah (2012) and Wan-Mohtar et al. (2019). Samples of all 16 formulations of banana jam were spread onto bread and served to the panellists in a random order. The colour, taste, aroma, texture, appearance, and overall acceptance of the jams were evaluated using the 9-point Hedonic scale (1 = extremely poor, 2 = very poor, 3 = poor, 4 = below fair above poor, 5 = fair, 6 = below good above fair, 7 = good, 8 = very good, 9 = excellent).

RESPONSE SURFACE METHODOLOGY (RSM)

Optimisation of the banana jam formulation was performed using RSM (Minitab 17 Software ; Minitab Inc., State College, PA, USA) as according to Wan-Mohtar et al. (2020) on optimized mixed-ratio chicken patty, through the central composite design (CCD) 2^3 + star with a total of 16 runs. The independent variables were the amount of sugar (175-275 g), amount of pectin, (3-7 g), and volume of citric acid (150 mL - 234 mL) (Table 1). The dependent variables or responses (Y) are the physicochemical analysis (pH, total titratable acidity, water activity, ^{0}Brix, L*) and the sensory attributes score (colour, taste, aroma, texture, and overall acceptability). The responses were fitted to a second order polynomial model (2).

TABLE 1. Optimization of the banana jams formulation through the response surface methodology (RSM). Response surface methodology was done using the central composite design (CCD) 2^3 + star with a total of 16 runs. The independent variables were the amount of sugar (175-275 g), amount of pectin (3-7 g) and volume of citric acid (150-234 mL)

Run order	Independent variables		
	Amount of sugar (g)	Amount of pectin (g)	Volume of citric acid (mL)
1	225.0	5.00	119.34
2	275.0	3.00	150.00
3	175.0	3.00	234.00
4	275.0	3.00	234.00
5	275.0	7.00	234.00
6	311.5	5.00	192.00
7	225.0	8.46	192.00
8	225.0	5.00	264.66
9	225.0	1.54	192.00
10	275.0	7.00	150.00
11	175.0	7.00	150.00
12	175.0	3.00	150.00
13	175.0	7.00	234.00
14	138.5	5.00	192.00
15	225.0	5.00	192.00
16	225.0	5.00	192.00

$$Y = I + ax_1 + bx_2 + cx_3 + dx_1^2 + ex_1x_2 + fx_1x_3 + gx_2^2 + hx_2x_3 + ix_3^2 + \varepsilon \quad (2)$$

where Y is the measured response; I is a constant; a, b, and c are linear coefficients for the first order; d, g, and i are square coefficients; e, f, and h are interaction coefficients; x_1, x_2, x_3, x_1^2, and ε is the error.

STATISTICAL ANALYSIS

Statistical analyses were conducted using the Minitab 17 software. One-way analysis of variance (ANOVA) with

Tukey's multiple comparisons were performed. The values were expressed as a mean ± standard deviation to determine the significant differences among means for all testing at *p*-value of 1 at α = 0.05.

RESULTS AND DISCUSSION

PHYSICOCHEMICAL ANALYSES TOTAL SOLUBLE SOLID (°BRIX) AND WATER ACTIVITY

In Table 1, the results show that different amounts of sugar added to the jams affected the water activity and °Brix while the amount of pectin and volume of citric acid remained unaffected in all jams. Sugar promotes hydrophobic interactions between pectin chains by decreasing water activity (Shinwari & Rao 2020). Similarly, Kanwal et al. (2017) stated that different treatments can affect the water activity in guava jam. No interactions were found between the independent variables and the water activity and °Brix.

COLOUR ANALYSIS

According to Figure 6, Lightness (L*) was shown not to be influenced by the amount of sugar and pectin and volume of citric acid added in the banana jams. However, the interaction between the amount of pectin and volume of citric acid used was found to influence the L* of the jams can be seen in Figure 6. Abid et al. (2018) reported that pectin concentration influences colour of pomegranate jam. Degradation occurred for anthocyanin-binding systems and the red colour of all samples tended to disappear mainly due to anthocyanins thermal degradation and pectin esterifications during heating process (Fernandes et al. 2020). Aksay et al. (2018) showed that citric acid played a role in the changes in L* in banana jams.

pH ANALYSIS

Based on Figure 6, results from the pH analysis showed that the volume of citric acid had a linear effect on the pH of the banana jams. The interaction between the amount of sugar and volume of citric acid was shown to influence the pH of the jams also shown in Figure 6. Ngoh Newilah et al. (2018) reported that as the quantity of pulp increases, the pH of jam produced using CARBAP K74 fruit harvested either from Njombé or Bansoa increases due to the low titratable acidity of the CARBAP K74 pulp. Kanwal et al. (2017) stated that intervals pH decreases due to increase in acidity during storage which leads to breakdown of pectin during storage and ascorbic acid is also decreased in storage and forms dehydro ascorbic acid from oxidation of ascorbic acid.

TOTAL TITRATABLE ACID (TTA) ANALYSIS

Figure 1 shows the volume of citric acid had a linear effect on TTA, while interactions between sugar and acid and between pectin and acid were found to have influenced the TTA of the banana jams. Kanwal et al. (2017) stated that the interaction of pectin and acid can be explained due to the breakdown of pectin in to pectinic acid during preparation of jam. Thus, the acidity value increases.

FITTING THE MODEL WITH RESPONSE SURFACE METHODOLOGY (RSM)

Based on the statistical analysis, the independent variables that showed no significant influence (*p* > 0.05) on the physicochemical properties were eliminated to obtain the model. R^2 values indicated the accuracy between the predicted values and experimental results for the measured response. All physicochemical analyses showed low R^2 values, indicating that the variance in sugar and pectin content and volume of citric acid contribute low variance with respect to water activity (R^2 = 33.74 %), °Brix (R^2 = 32.64 %), L* (R^2 = 48.47 %), and pH (R^2 = 63.05 %) for all banana jams except for TTA (R^2 = 77.50 %). Therefore, only TTA was selected for the identification of the optimum range area as follows:

$$Y_1 = -1.308 + 0.003118\,S + 0.2784\,P + 0.00420\,A \quad (3)$$
$$- 0.000638\,SP - 0.000640\,PA$$

where Y_1 is TTA; S is ***B*** coefficient of sugar; A is ***B*** coefficient citric acid; SP is ***B*** coefficient of the interaction between the amount of sugar and pectin; and PA is ***B*** coefficient of the interaction between the amount of pectin and volume of citric acid. Nonetheless, different variables should be investigated or added to the experiments to obtain higher R^2 values. The inclusion of additional axial points is necessary to adjust the model to a larger order (second degree) (Silva et al. 2012). Lee et al. (2006) studied the effects on the quantity of pulp and sugar and the cooking time to improve the R^2 for all responses. Overall, the optimal formulation based on the ideal physicochemical properties of the banana jam was 297.52 g of sugar 4.23 g of pectin and 264.66 mL of citric acid (water activity = 0.80 a$_w$, target 65 °Brix, pH 3.35 TTA = 0.39 %, and maximum L*). Khan et al. (2020) showed that jams consists of total soluble substances of about 68.5 % and at least 45 % of fruit pulp. Addition of pectin and acids is critical to meet a minimum pectin requirement of 1% and pH 3.0, as gel network is formed by pectin with specific TSS and pH (Shinwari & Rao 2018). The U.S. Food and Drug Administration (FDA) has suggested a water activity (a$_w$) < 0.85 aw in a finished food product (Garces-Vega et al. 2019).
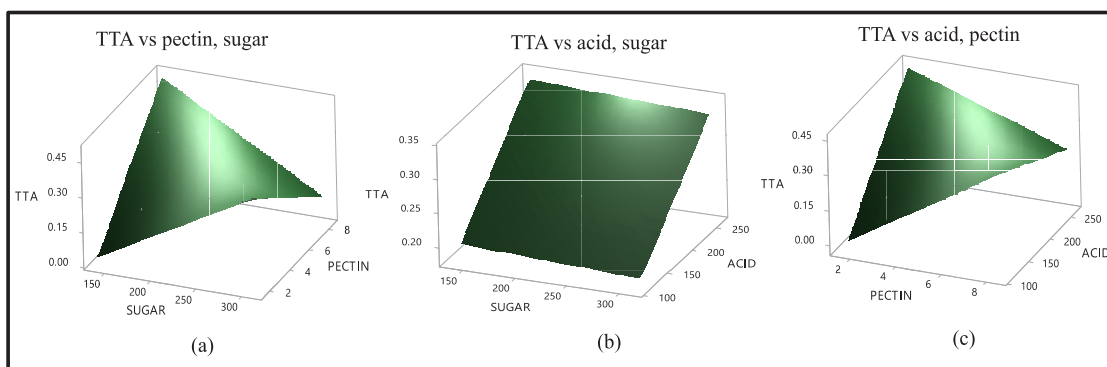
FIGURE 1. Response surface plot for the effect of (a) quantity of sugar and pectin, (b) quantity of sugar and citric acid, and (c) quantity of pectin and citric acid on total titratable acidity (TTA) of banana jam. The banana jams with different amount of sugar (175-275 g), pectin (3-7 g) and concentration of citric acid (150-234 mL) were treated with phenolphthalein and titrated with sodium hydroxide

Figure 1 shows the surface plot of the effect of sugar and pectin amount and volume of citric acid on the TTA in banana jam. A high sugar content (300 g) was found to increase the TTA (0.35 %) with a high volume of citric acid (250 mL) (Figure 1(b)). Commercial strawberry jam recorded highest total titrable acidity (0.68 ± 0.00) in jam with the highest total soluble solids (51.00 ± 0.00) influenced by the amount sugar content (Makanjuola & Alokun 2019). Similarly, Napio (2018) found that the highest amount of sugar (57.70 g) in shea fruit jam had the highest TTA value (0.31 ± 0.07 %). Pectin (8 g) and citric acid (250 mL) were found to reduce the TTA (0.30 %) in banana jams (Figure 1(c)). This result can be attributed to the interaction of H^+ ions with pectin networks (Evageliou et al. 2000).

SENSORY EVALUATION

Sensory evaluation on the colour, taste, aroma, and overall acceptability on the banana jams showed that the no. 16 banana jam was the most preferred by the 30 panellists. Jam no. 4 had the best texture (Figure 2), while jam no. 14 (138.5 g sugar, 5 g pectin, and 192 mL citric acid) was the jam least preferred by the panellists and had the lowest amount of sugar, which caused the jam to appear runny due to reduced gelation and light in colour. Similarly, Ahmed et al. (2016), reported that low level of sugar causes a decrease in the caramelised brown colour of sapodilla jam.
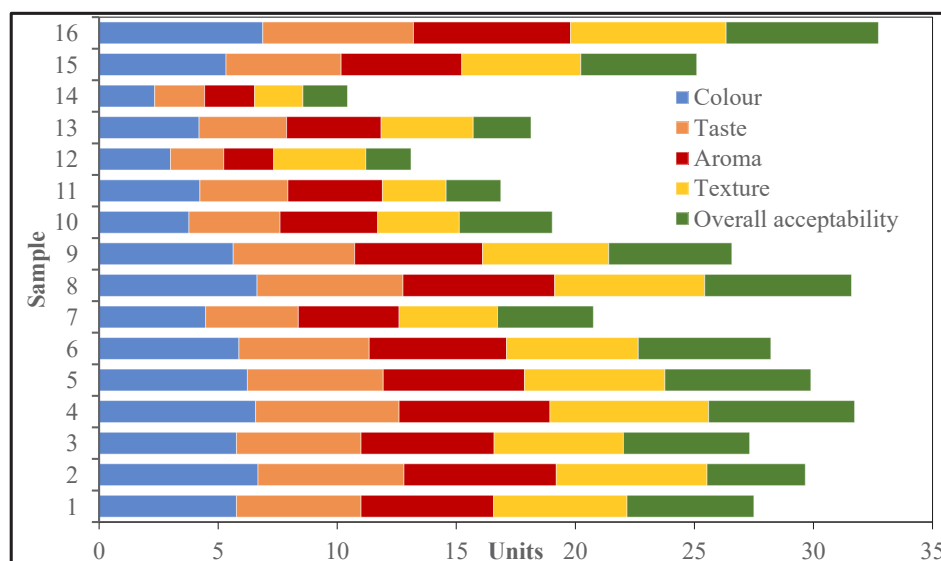

FIGURE 2. Sensory evaluation on the texture on banana jams. The thirty panellists were chosen from local Malaysians from the Food Science Department, Universiti Putra Malaysia, Serdang, Selangor, Malaysia. A total of sixteen different formulated banana jams were spread on breads to be given to the panellists for sensory evaluation

Statistical analysis on the colour ($R^2 = 70.86$ %), taste ($R^2 = 71.78$ %), aroma ($R^2 = 70.50$ %), texture ($R^2 = 80.10$ %) and overall acceptability ($R^2 = 73.25$ %) showed that the amount of sugar had a linear and quadratic effects on all the sensory attributes of the banana jams. Conversely, the amount of pectin used had only linear and quadratic effects on the texture of the banana jams, while the volume of citric acid had a linear and quadratic effect on both the texture and overall acceptability of the banana jams.

FITTING THE MODEL FROM THE RESPONSE SURFACE METHODOLOGY (RSM)

Sensory analysis results were fitted to a model to determine the effects of the amount of sugar and pectin and volume of citric acid on the colour (Y_2), taste (Y_3), aroma (Y_4), texture (Y_5), and overall acceptability (Y_6) of the banana jams ((4) - (8)). R^2 indicated that the predicted values and experimental results for the colour ($R^2 = 70.86$ %), taste ($R^2 = 71.78$ %), aroma ($R^2 = 70.50$ %), texture ($R^2 = 80.10$ %), and overall acceptability ($R^2 = 73.25$ %) were comparable. The quadratic and interaction terms for pectin and the volume of citric acid were removed from the final model as they did not significantly affect the sensory attributes ($p \geq 0.05$). The optimal formulation based on the ideal sensory properties of banana jam was predicted to be achieved with the addition of 262.571 g of sugar, 1.54 g of pectin, and 264.66 mL of citric acid.

$$Y_2 = -10.99 + 0.1208\,S - 0.200\,P + 0.01122\,A - 0.000230\,SS \quad (4)$$

$$Y_3 = -10.36 + 0.1092\,S - 0.172\,P + 0.01071\,A - 0.000202\,SS \quad (5)$$

$$Y_4 = -11.40 + 0.1182\,S - 0.158\,P + 0.01130\,A - 0.000220\,SS \quad (6)$$

$$Y_5 = -11.00 + 0.1217\,S - 0.3022\,P + 0.01154\,A - 0.000231\,SS \quad (7)$$

$$Y_6 = -13.97 + 0.1281\,S - 0.167\,P + 0.01568\,A - 0.000238\,SS \quad (8)$$

where Y_2 is colour; Y_3 is taste; Y_4 is aroma; Y_5 is texture; Y_6 is overall acceptability; S is the amount of sugar; A is volume of citric acid; SS is the interaction between the amount of sugar.
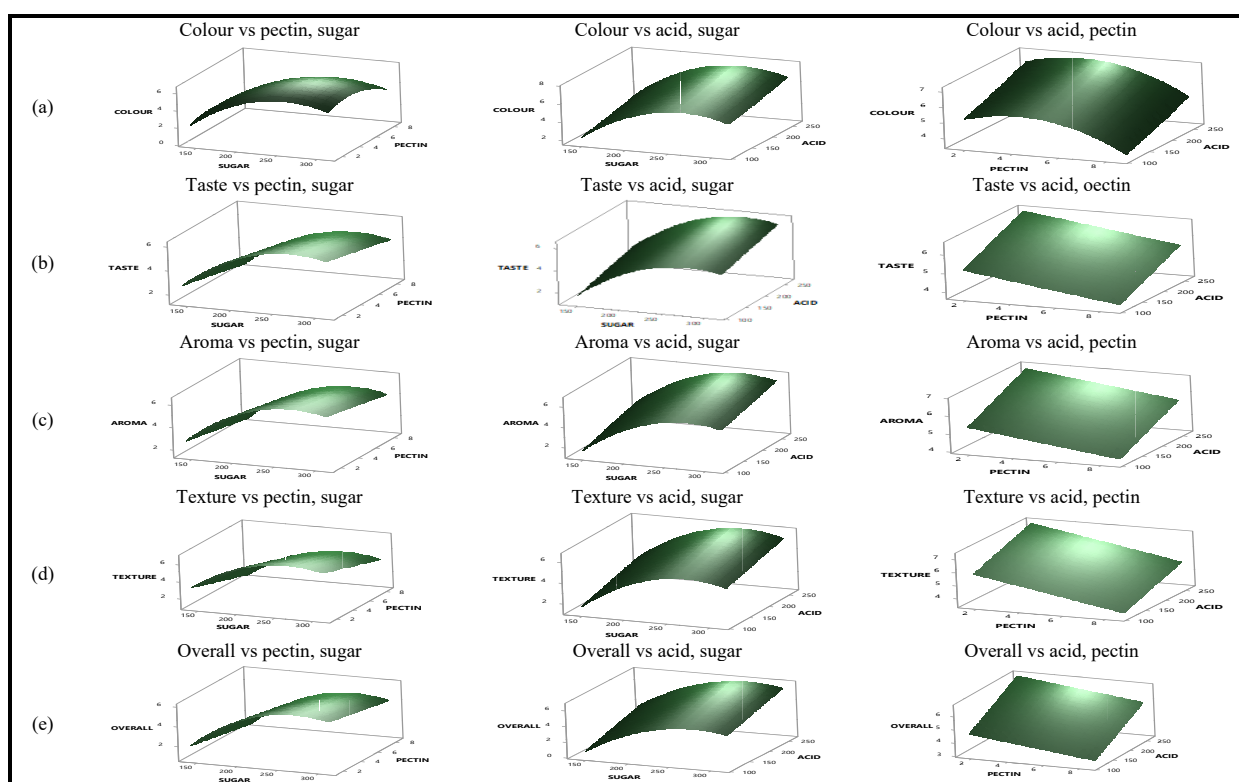

FIGURE 3. Surface plots for the colour (a), taste (b), aroma (c), texture (d) and overall acceptance (e) of the banana jams against the amount of sugar (175-275 g) and pectin (3-7 g) and concentration of acid (150-234 mL)

Figure 3 shows the surface plot for the effect of the amount of sugar and pectin and volume of citric acid on the sensory quality of the banana jams. Sugar was found to influence all sensory attributes of the banana jam. Flavour and aroma enhancement in the banana jam with incremental increase in sugar usage were attributable to the occurrence of the Maillard reaction during the cooking process. The Maillard reaction is a browning reaction that takes place when reducing sugars react with amino acids to form Maillard reaction products (MRPs) (Teodorowicz et al. 2017). The increase in sugar levels triggered an increased Maillard reaction in the banana jam, thus enhancing its flavour and aroma. Besides flavor, colour and texture, the quality of jam is evaluated by the aroma as the sensory indicator (Zhang et al. 2020). Esters are the major group of volatile aroma compounds in banana includes alcohols and aldehydes (Shivashankara 2016). A previous study reported on the various sensory profiles of pineapple jams using different formulations of sugar, pectin, and citric acid (Bierhals et al. 2011).

Sugar was also observed to affect the texture of the banana jam. The banana jam samples with lower amounts of sugar had a runny appearance. Rýdlová et al. (2020) reported that parameter (L*) of prepared strawberry spreads shows that the addition of sugar significantly reduces product lightness ($p= 0.001$). In addition, samples containing 40-50 % of strawberry puree and 30-40 % of sugar achieved the highest gel stiffness and samples without strawberry puree and low sugar content (10-20 %) showed low gel stiffness (Rýdlová et al. 2020). Sucrose is an appropriate sugar for jam production as it has less potential for re-crystallisation compared to glucose (Ahmed et al. 2016). Akesowan and Choonhahirun (2019) indicated that the use of sucrose in a jam could affect the texture of konjac gel due to a bulking effect. Sucrose competes with xanthan for available water molecules, affecting the structural rigidity. However, the researchers discovered that the substitution of erythritol-sucralose (ES) in konjac gel did not have any effect on its texture.

Subsequently, Quintana et al. (2018) reported that sugar concentration and type of hydrocolloid had an effect on the texture of soursop jam. Furthermore, sucrose forms rigid gels to obtain a desirable texture, and higher amounts of sugar improve the viscosity of jam (Ahmed et al. 2016). Furthermore, Ahmed et al. (2016) also reported that high sugar concentrations result in the most preferable colour, texture, taste, flavour, and overall acceptability for sapodilla jam.

The amount of pectin and volume of citric acid were also found to improve the texture of the banana jam.

Siddiqui et al. (2015) reported on the increased viscosity of sapodilla jam with a gradual increase in amount of pectin.

According to the FAO (2016), a pH of 3.0-3.3 is preferred for proper gelation of a jam. Pectin is the major factor affecting the consistency and hardness of gel (Banaś et al. 2018). Pectin strands carries negative electric charges and can be neutralised by the addition of acid, which decreases the pH of the jam mixture; hence, the pectin strands form a network which can set the jam (Bekele et al. 2020). Barbieri et al. (2018) stated that the gelation of jam occurs from the high temperature during cooking process and process of gelation of high methoxyl pectin. Jam can be observed as good quality by its vivid color, maintain the original fruit's flavour, intermediate consistency and texture; however, these characteristics of jam may be varied during storage (Brandão et al. 2018).

SHELF LIFE STUDY

Anggraini et al. (2019) stated that the higher the temperature storage, the faster the damage of the product will be. Ascorbic acid decreases due to oxidation and enzymatic catalytic reaction within the mass of jam during storage (Khan et al. 2020). The banana jams stored at 25 °C had developed mould by day 7 (Figure 4(a)). However, some banana jams developed mould in a shorter time due to differences in the amount of sugar and acidity of the jams. Sugar present in jam reduces its water activity resulting in longer shelf life (Shinwari & Rao 2018). Makanjuola and Alokun (2019) stated that the importance of high acidity in food products shows that food product can be stored before spoilage or deterioration takes place. Similarly, Tifani et al. (2018) reported that increasing the acidity of durian jam enhanced its shelf life as it protected the jam from microorganisms.

In contrast, the banana jams stored at 4 °C remained in good condition with no mould up until day 14 (Figure 5(a)). At 4 °C, lower water activity and higher total soluble solids (sugar content) in the banana jams contributed to prolonging the shelf life of the jams. Water activity (Aw) is critical to ensure for food safety by reducing it for increased shelf life and reduced microbial activity (Lopez-Malo & Alzamora 2015). In addition to enhancing flavour and texture, sugar acts as preservative and aids in inhibiting microbial growth (Benmeziane et al. 2018). A high level of sugar is usually associated with low water activity and moisture content, making the environment unsuitable for microbial growth (Benmeziane et al. 2018). Sugars bind water molecules, leading to a reduction in water activity (Kanwal et al. 2017). Similarly, Martinsen et al. (2020) reported that the stability of anthocyanins of jam was higher at the lowest storage temperature (4 °C) compared to at room temperature.
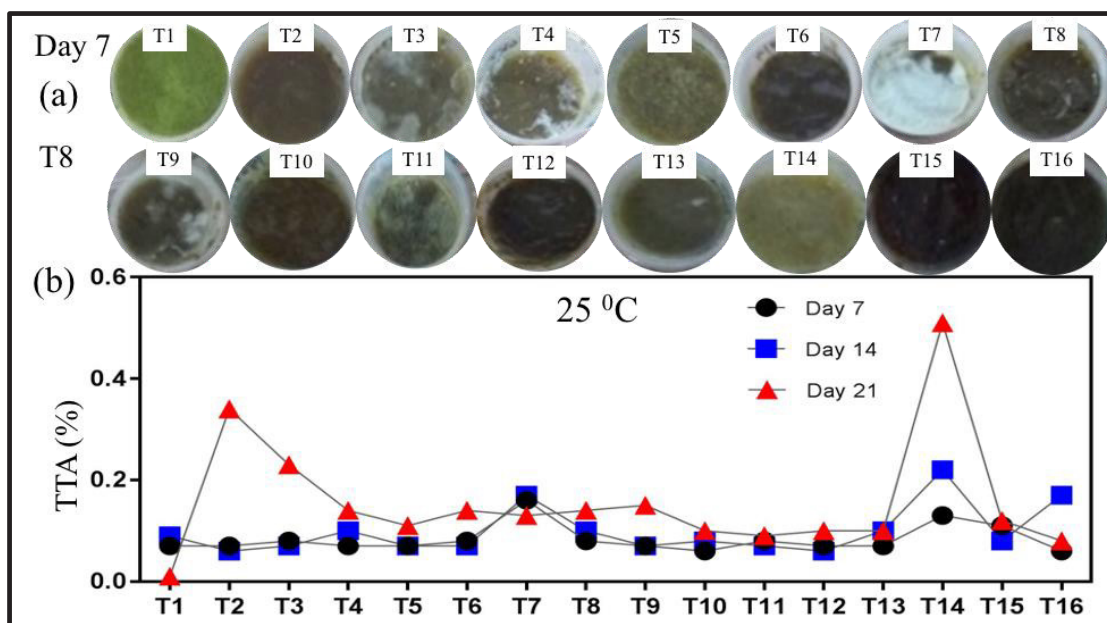
FIGURE 4. Condition of the banana jams stored at 25 °C up until day 7 (a) and the change in the total titratable acid (TTA) (%) in the banana jams at day 7, 14 and 21. The error bars were too small to be represented in the graph
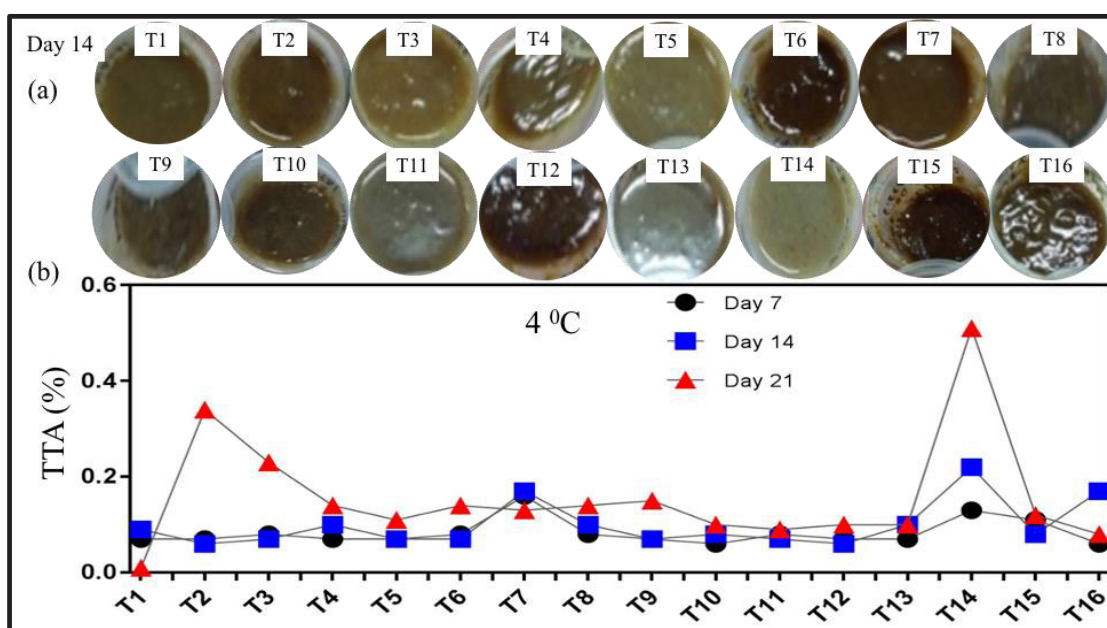

FIGURE 5. Condition of the banana jams stored at 4 °C up until day 14 (a) and the change in the total titratable acid (TTA) (%) in the banana jams at day 7, 14 and 21. The error bars were too small to be represented in the graph

The pH and TTA of the banana jams showed that there were no significant differences ($p \geq 0.05$) in the banana jams stored at both temperatures (Figure 4(b) and 5(b)). This finding may be attributable to a narrow range of sugar and pectin quantity and volume of citric acid used in making the banana jams. pH and TTA are related to acidity, which is important in determining the quality of a food product. According to Asema and Parveen (2018), the adequate level of acidity is important for gel formation. If there is too little acid, the gel will never set and if there is too much acid, the gel will lose liquid. Other than that, the acidity of a food product represents the stability and

shelf life of that product (Kanwal et al. 2017). Similarly, Brandão et al. (2018) observed pH stability in cerrado fruit jam during storage. Conversely, Shah et al. (2015) reported that decreasing trend in pH of apple and olive jam during storage might be due the hydrolysis of pectic bodies and formation of acidic compound during degradation of sugar contents. Ngoh Newilah et al. (2018) observed a significant increase in TTA in jams stored at 25 °C as the storage period increased, due to an increase in the concentration of weakly ionised acids and their salts. Overall, the optimal formulation of banana jam for the best quality and safety was found to be 281.79 g of sugar, 4.13 g of pectin, and 264.66 mL of citric acid (Figure 6).
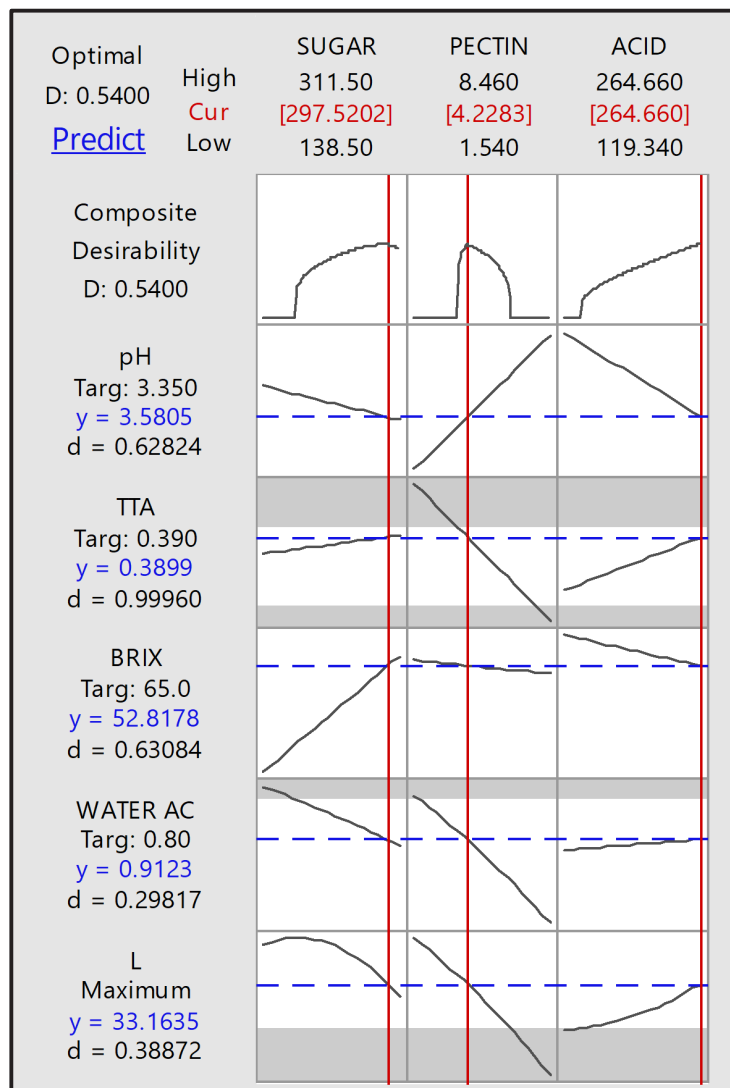

FIGURE 6. Predicted optimal formulation for the preparation of the banana jam with the best quality was 281.79 g of sugar, 4.13 g of pectin and 264.66 mL of citric acid with water activity = 0.80 aw, °Brix = 65 %, pH = 3.35, TTA = 0.39 % and maximum L*

Conclusion

Physicochemical analyses showed that the amount of sugar and pectin and the volume of citric acid affected the TTA and pH of banana jam. Water activity and °Brix were only influenced by the amount of sugar added to the jam. Lightness (L*) was affected by the amount of pectin and volume of citric acid. Subsequent sensory analyses showed that the amount of sugar affected the colour, aroma, taste, texture, and overall acceptability of the banana jams. Furthermore, banana jams stored at 4 °C showed higher stability and better shelf life due to high total soluble solids (sugar content), which lower the water activity and moisture content compared with those stored at ambient temperature (25 °C). Overall, the predicted optimal formulation for the preparation of banana jam with the best quality (water activity = 0.80 aw, °Brix = 65%, pH = 3.35, TTA = 0.39 %, maximum L*) and safety was 281.79 g of sugar, 4.13 g of pectin, and 264.66 mL of citric acid. Taken together, these findings support the pre-commercialisation potential of *Musa cavendish* banana using the most efficient formulation for jam preparation.

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