OPTIMIZATION OF FACTORS INFLUENCING ON THE QUALITY OF LUCUMA (*Pouteria lucuma*) JAM

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Abstract – *This research aims to survey the factors in the process of quality of lucuma jam (Pouteria lucuma). The main contents included (i) Investigating the effects of added water (v/w) (60%, 80%, 100%, 120%, 140%); (ii) Optimize the ratio of sugar (50%, 60%, 70%), acid citric (0.2%, 0.3%, 0.4%) and pectin (0.5%, 1.0% and 1.5%). The results showed that by adding 100% water, the jam product achieved the highest sensory score and attractive color for L*, b* of 30.12 , and 30.96, respectively. The ratio of sugar (70%), citric acid (0.2%) and pectin (1.0%) in the supplementary mixture resulted in a total polyphenol of 21.53 mgGAE/L and 62.67^{o}Bx of the final product and gained the highest scores from the sensory panel, which evaluated the jam by perceptive color, flavor, taste , and texture.*

Keywords: jam, lucuma (Pouteria lucuma), lucuma jam.

I. INTRODUCTION

Lucuma is a quite common fruit cultivated throughout Vietnam, and it has a high fruit yield but a low economic value. Lucuma is a culturally important food that has been used for nutrition for a long time [1]. The fruit has a naturally sweet taste and contains a large amount of β-carotene, protein, carbohydrates, fiber, vitamins, and minerals such as iron, calcium, and phosphorus. Types of sugar found in 100 grams of lucuma flesh are glucose (8.4 g), fructose (4.7 g), sucrose (1.7 g), and inositol (0.06 g). Moreover, the flesh of the fruit contains many nutrients, especially antioxidant components necessary for the body's activities. They help increase the red blood cell count, stimulate the nervous system, combat depression, reduce cholesterol and triglycerides in the blood, prevent cardiovascular diseases and obesity, limit heart muscle ischemia, enhance immune system effectiveness, and provide a good source of energy [2].

While lucuma fruit is a commonly consumed fresh fruit, the main processed products are in the form of supplemental powder in ice creams, candies, and nutritional porridge. There hasn't been much research on processed lucuma products, including lucuma jams. Such jams and preserves are very convenient for quick breakfasts and offer a complete nutritional value, and can be supplemented with various types of cream fillings to create diverse baked goods that increase value and attract consumers. Due to a lack of studies on lucuma jam, it is essential to research and create new products from lucuma fruit to enhance its economic value and diversify fruit jams in Vietnam [3].

II. LITERATURE REVIEW

Jam is a popular food, processed from fresh fruits or processed fruits (fruit puree, fruit juice) cooked with sugar to a level of 60–70%, supplemented with pectin or agar to create gel [3]. Many studies in and out of the country have researched the sugar concentration, acid concentration, types of additives, and factors affecting the quality of jam products. Basu et al. [4] conducted a study on the effect of pectin concentration, sugar concentration, and citric acid concentration on mango jam products. The results showed that the highest satisfaction was achieved with a sugar concentration of 65%, pectin concentration of 1%, and pH of 3.4. Dong Truc Phuong and Nguyen Thanh Trung [5] studied the separation of gac fruit from seeds, then ground and mixed with varying sugar concentrations (60%, 70%, 80%, 90%) and citric acid concentrations (0.8%, 1%, 1.2%, 1.4%) and condensed to 55^{o}Bx. The best evaluation was obtained with a formulation

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ratio of 80% sugar, 1% citric acid, and 1% pectin. Another study by Nguyen Kim Phung [6] on wood apple fruit showed that by adding 100% of water, a jam product was obtained with the highest sensory score, an acid concentration of 0.3%, and a dry matter content of 50^oBx. The best formulation ratio of pectin to carrageenan was 0.7:0.6, creating a stable and preferred product structure. Dang Thi Yen [7] studied the use of Hibiscus flowers in the production of strawberry jam. The results showed that the ratio of strawberries to hibiscus was 40% (strawberries: hibiscus mixed at a ratio of 90:10), citric acid concentration of 0.2%, and pectin concentration of 0.5%. The condensation process was carried out at 80–90^oC for 25 minutes.

In some studies specifically about lucuma, lucuma fruit dried at 60^oC for 08 hours, achieved a moisture content of 8.67%. Lucuma fruit powder products have a high content of antioxidants such as vitamin C and total carotenoids, especially β-carotene, which are beneficial for health [8]. According to a study by Tran Xuan Hien et al. [9], when lucuma fruit juice was condensed at 75^oC for 50 minutes, the total polyphenol content and antioxidant activity of the condensed lucuma fruit juice were 7.69 mgGAE/g and 73.82%, respectively. Despite its high nutritional content, the utilization of this raw material to produce high-value economic products has not been well-explored. In that context, lucuma jam was studied to enhance the economic value of lucuma fruit, diversify jam products, and create new delicious products to fit the demands and preferences of consumers.

III. MATERIALS AND METHODOLOGY

A. *Ingredients, chemicals*

Ingredients: Lucuma fruits were purchased from gardens in Tra Vinh Province. Only ripe and disease-free fruits were selected, with uniformly yellow skins and a distinctive aroma of ripe lucuma. Lucuma fruit were stored at room temperature for about 3 days to fully ripen and be processed.

Additives: Saccharose (99.8%) (Vietnam), citric acid (99.5%) (China), pectin HMP (99.5%) (India).

B. *Research methods*

Lekima fruit was washed of impurities and dirt on the surface, the skin and seeds were removed, and the fruit pulp (100 gr) was diluted with water as required. Then it was mixed to obtain a ratio of sugar (50%), citric acid (0.3%) and pectin (1%). This was stirred with a homogenizer to dissolve all additives, then concentrated at a temperature of 70^oC for 10 minutes before pouring the hot jam into washed bottles and cooling the product to complete the gelation process.

Monitoring parameters: color measurement and sensory evaluation (color, odor, taste, texture).

(i) Investigating the effect of additional water content: This experiment was designed with one factor, which was the amount of added water (60%, 80%, 100%, 120%, 140%) with three replicates.

(ii) Optimization of lucuma jam making process with additives: This experiment had three factors, including sugar (X_1), pectin (X_2), and citric acid (X_3) ratio. The experimental factors were designed according to the Box-Behnken method (Table 1).

Table 1: Experimental arrangement for optimization according to the Box-Behnken method

Pattern	X_1 (%)	X_2 (%)	X_3 (%)
--0	50	0.5	0.3
-0-	50	1	0.2
-0+	50	1	0.4
-+0	50	1.5	0.3
0--	60	0.5	0.2
0-+	60	0.5	0.4
000	60	1	0.3
000	60	1	0.3
000	60	1	0.3
0+-	60	1.5	0.2
0++	60	1.5	0.4
+-0	70	0.5	0.3
+0-	70	1	0.2
+0+	70	1	0.4
++0	70	1.5	0.3

Monitoring indicators: Brix, brightness, polyphenols content, sensory evaluation (color, odor, taste, and texture).

C. Analysis methods

- Moisture content was analyzed using an oven-dry method in which samples were dried at 105^{o}C to achieve a constant weight. The percentage of moisture for the different samples was then measured on the basis of their initial weight. The loss in weight was reported as % moisture [10]

- The method of determining the content of soluble solids (Brix) using a photometer (Master -4a-Atago, Japan) is based on the light refraction of sugar and some other organic compounds converted to sugar, to determine the concentration of dissolved solids.

- pH is determined by pH meter Hanna, Romania.

- Color measurement is done using Artweaver 1.0 software to obtain the R, G, and B values from digital images. Software is then used to adjust and convert the R, G, and B values to L*, a*, b*.

- Determination of content of phenolic compounds by using the Folin – Ciocalteu method, the gallic acid standard curve was developed, and TPC content was determined based on the standard curve [11].

- Sensory evaluation: Sensory evaluation of jam products is done using the scoring method according to Vietnam Standard No 3215-79. The sensory evaluation panel consists of 13 members who have expertise in evaluating food quality. The attributes of the jam are described, including color, odor, taste, and texture. Each attribute is rated on a descriptive scale from 1 to 5 [12].

D. Data analysis

Experimental results were replicated three times and statistically processed using JMP 9.0.2 (SAS Institute Inc., 2011; USA) and Microsoft Excel 2007 (Microsoft Corp., 2007; USA). The data show the mean of 3 replicates within the significance value (p < 5%).

IV. RESULTS AND DISCUSSION

A. Basic physicochemical composition of lucuma fruit

The process of making jam is influenced by many factors, such as fruit and technology, in which the initial composition of ingredients such as moisture content, Brix, acidity and total phenolic content play an important role and directly affect the quality of the product. The basic components of lucuma fruit were analyzed in Table 2.

Table 2: Basic chemical composition of lucuma

Parameters	Quanlity
Moisture (%)	59.98 ± 0.04
Brix	12.33 ± 0.57
pH	5.33 ± 0.12
Acidity (%)	40.06 ± 0.78
Total phenolic content (mgGAE/L)	241.20 ± 0.41

B. The influence of added water content on the color of the product

The influence of dilution ratio on the color of the product was investigated at five levels, with the water content increasing from 60% to 140% (100 gr of the fruit was considered as 100%). The results of the statistical analysis showed that the dilution ratio had a significant effect on the color of the product, as shown in Figure 1 with a significance level of 95%. The more added water content, the lighter the color of the product becomes, corresponding to an increase in the L* value from 27.46^e to 34.09^a. The yellow color decreases progressively, corresponding to the b* value ranging from 25.07^e to 34.08^a.

Color is an important factor for fruit jam, sensory evaluation is necessary in choosing the appropriate dilution ratio. Lucuma jam products were evaluated by sensory panelists who were lecturers and students from the Post-harvest Technology Center, Tra Vinh University. The results of the sensory evaluation scores for the color and aroma of the product are shown in Table 3. The sensory evaluation results show that changing the water content greatly affects sensory characteristics such as color, aroma, taste, and texture. When the water content is increased, the color becomes lighter yellow and the aroma of lucuma decreases significantly, losing its characteristic lucuma scent. When the water content is added in a small amount of 60%, the color becomes very dark yellow and the lucuma aroma is still

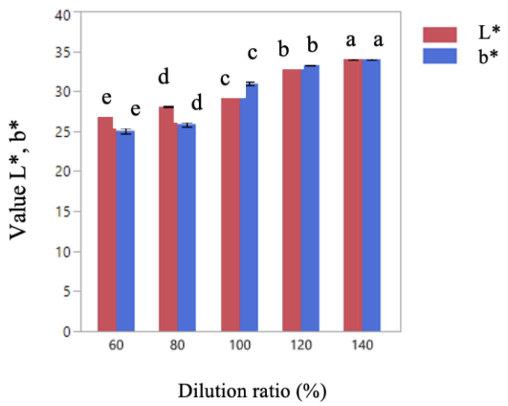


Fig. 1: The effect of dilution ratio on the L* and b* values

Note: Different letters represent the differences in treatments at significance level $p < 0.05$

prominent, making the product less preferred. When 100% water is added, the product is evaluated with the highest sensory scores for color, aroma, taste, and texture, corresponding to scores of 4.63[a], 4.36[a], 3.46[a], and 4.72[a], respectively.

Table 3: Influence of dilution ratio on sensory value

Dilution ratio	Color	Smell	Taste	State
60	1.77[e]±0.62	1.97[c]±0.77	2.41[c]±0.49	2.05[d]±0.75
80	2.69[d]±0.65	3.15[b]±0.74	3.17[b]±0.72	2.62[c]±0.59
100	4.63[a]±0.49	4.36[a]±0.53	3.46[a]±0.51	4.72[a]±0.45
120	3.31[b]±0.61	3.03[b]±0.70	3.46[a]±0.51	3.03[b]±0.70
140	2.97[c]±0.74	2.97[b]±0.93	3.54[a]±0.51	3.13[b]±0.69

C. The influence of sugar, citric acid, and pectin ratio on product quality

The addition of sugar to jam not only provides sweetness but also helps preserve the fragrance of the product. A high sugar content helps reduce water activity in the product, facilitating the processing and subsequent preservation. pH is a crucial factor in the production of jam, thus citric acid is added to achieve a pH of 3.1 to 3.5, corresponding to a high ratio of methoxyl pectin, creating a stable gel system for the jam. Different pectin ratios have a significant impact on the structure of the product [13].

Table 4: Experimental results for optimizing the formulation process

X_1	X_2	X_3	Polyphenol	Brix	L*	Sensory score
50	0.5	0.3	19.15±0.06	50.67±0.57	38.48±0.06	12.11±0.19
50	1	0.2	19.89±0.01	51.66±0.42	38.69±0.19	12.99±0.68
50	1	0.4	20.28±0.14	50.33±0.50	41.20±0.07	11.07±1.09
50	1.5	0.3	19.19±0.06	52.66±0.48	39.18±0.84	13.51±0.49
60	0.5	0.2	21.56±0.14	55.67±0.55	37.55±0.10	13.55±0.92
60	0.5	0.4	19.34±0.09	58.33±0.51	37.73±0.81	11.42±0.31
60	1	0.3	19.34±0.01	57.66±0.46	37.42±0.08	15.45±0.64
60	1	0.3	20.37±0.21	55.67±0.51	38.13±0.02	15.40±1.46
60	1	0.3	20.26±0.06	55.00±0.08	38.67±0.01	15.36±0.71
60	1.5	0.2	20.29±0.06	57.67±0.57	38.79±0.30	13.52±0.15
60	1.5	0.4	20.86±0.23	56.00±0.06	39.38±0.17	13.96±0.28
70	0.5	0.3	21.07±0.43	60.33±0.57	39.47±0.04	14.30±0.91
70	1	0.2	21.53±0.16	62.67±0.57	42.13±0.02	17.99±0.09
70	1	0.4	22.49±0.04	60.00±0.02	40.33±0.11	14.13±0.29
70	1.5	0.3	20.97±0.36	62.00±0.04	40.35±0.02	15.24±0.61

The results of the influence of sugar ratio, citric acid, and pectin are shown in Table 4.

Based on the variance analysis table determining the suitability of the model (Table 5), the Box-Behnken model-designed experiments were conducted to evaluate the influence of factors and the interaction between factors in the formulation process.

The analysis results indicate the suitability of the model, as shown by the lack of fit p-values for the polyphenol content, Brix, brightness L*, and sensory score, which are 0.929, 0.971, 0.931, and 0.993, respectively ($p > 0.005$). The R^2 value for polyphenols is 0.85, indicating an 85% suitability of the predicted value compared to the actual value. The R^2 value for Brix degree is 0.95, indicating a 95% suitability of the predicted value compared to the actual value. The R^2 value for L* brightness is 0.92, indicating a 92% suitability of the predicted value compared to the actual value. Finally, the R^2 value for the sensory score is 0.96, indicating a 96% suitability of the predicted value compared to the actual value. The PRESS value, p of the model > F, and F ratio of the model also demonstrate the reliability of the model for predicting the monitored variables during the process.

The quadratic equation represents the correlations between the experimental factors affecting the monitored variables.

Table 5: Results of variance analysis determine the adequacy of the model

No.	Polyphenol	Brix	L*	Sensory score
p lack of fit	0.929	0.971	0.931	0.993
R^2	0.847	0.946	0.922	0.959
Adjust R^2	0.808	0.932	0.902	0.949
PRESS	10.246	56.164	9.881	9.787
F ratio of model	21.578	68.036	46.042	91.886
p of model > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001

- Polynomial equation of degree 2 for polyphenol:

$Y_1 = 19.989 + 0.318X_1^2 + 0.740X_3^2 + 0.696X_2X_3 + 0.943X_1$

- Polynomial equation of degree 2 for Brix:

$Y_2 = 56.111 - 1.083X_2X_3 + 4.958X_1 + 0.416X_2$

- Polynomial equation of degree 2 for brightness L*:

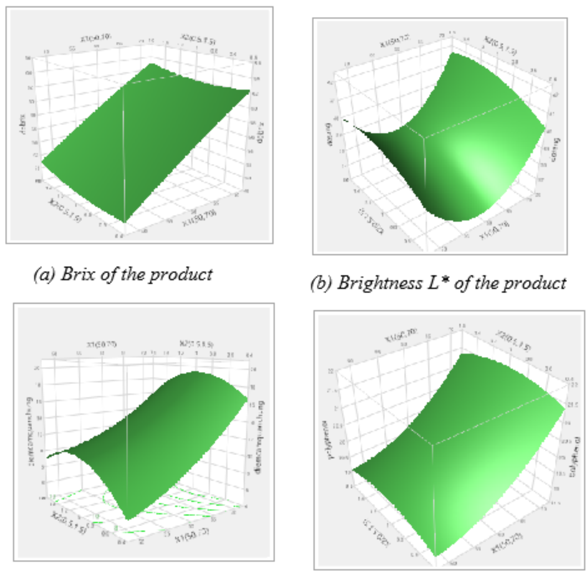
$Y_3 = 38.080 + 1.759X_1^2 - 0.467X_2^2 + 0.752X_3^2 - 1.076X_1X_3 + 0.592X_1 + 0.559X_2 + 0.185X_3$

- Polynomial equation of degree 2 for sensory evaluation:

$Y_4 = 12.075 - 2.105X_2^2 - 1.484X_1X_3 + 1.999X_1 - 0.935X_3$

Based on the results of the regression analysis, the influence of the variables in the process can be evaluated. The results show that the sugar and citric acid ratio are two factors that influence the sensory score of the product ($p < 0.05$), and the pectin and citric acid ratio influences the polyphenol content ($p < 0.05$). If the sugar ratio increases and the citric acid ratio decreases, the sensory score increases, and if the pectin ratio increases and the citric acid ratio decreases, the polyphenol content increases. The quadratic variables X_2^2 of the target variable, significantly affect the monitoring variable ($p < 0.05$), but the other variables of the sensory and polyphenol targets do not have a significant effect. For the Brix target, the pectin and citric acid ratio interact with each other and affect the Brix of the product ($p < 0.05$), while the other variables do not have a significant effect ($p > 0.05$). The quadratic variables of the sugar, pectin, and citric acid ratios significantly affect the brightness (L*) ($p < 0.05$).

The response surfaces show that the sugar, pectin, and citric acid ratios interact with each other and influence the monitoring targets. For the sensory quality target based on the overall sensory score of each experimental sample, the optimized response surface chart (Figure 2(c)) shows that the sample with the highest sensory score (17.99) is achieved at a sugar, pectin, and citric acid ratio of (70%, 1%, 0.2%), resulting in a moderately sweet taste, bright yellow color, characteristic aroma of lucuma, and smooth surface texture.



(a) Brix of the product

(b) Brightness L of the product*

(c) Sensory evaluation of the product

(d) Polyphenols of the product

Fig. 2: Surface plot graph showing the factors influencing the quality of the product

The results shown in Figure 2(a) indicate that the Brix of the product is always higher than that of the mixture, due to the heat treatment, water evaporation increases the Brix of the product. The results also show that the concentration of the formulated acid does not affect the sugar content. Brix level and sugar content are interdependent, as Brix level increases, the sugar content increases from 50 to 70%, as sucrose is hydrolyzed into glucose and fructose in an acidic environment, the soluble dry matter in the jam mainly consists of sugar [14]. The highest Brix is 62.66 with the corresponding ratio of sugar, pectin, and citric acid (70%, 1%, and 0.2%).

Color is one of the important factors for jam products, and the preferred color for lucuma jam is bright yellow, not too dark. When the added sugar content is higher, under the effect of temperature, it is easy to make the product's color dark (Maillard reaction occurs), and the smell and taste are also affected. The analysis results show that when the concentration of sugar and acid changes, the color of the product changes, and the color of the jam becomes darker (the value of L* decreases) as the Brix value increases. The optimized response surface model for the optimum brightness value of L* is 42.13 at the corresponding ratios of sugar, pectin, and citric acid (70%, 1%, 0.2%), resulting in a bright yellow color, the characteristic even color of lucuma. This result is also consistent with some studies on jam such as jam of pond apple and soursop jam [15, 16].

The surface of the product is responsive to the content of polyphenols, which is affected relatively by the ratio of sugar, pectin, and citric acid. The highest polyphenol content was 22.49 mgGAE/L at the corresponding ratio of 70% sugar, 1% pectin, and 0.4% citric acid. The polyphenol content was insignificantly changed when the ratio of sugar, pectin, and citric acid was altered.

The results show that different Brix-pH will give sensory evaluation scores. Samples of 70% sugar, 1% pectin, and 0.2% citric acid, the highest evaluation scores were given to color, aroma, taste, and texture. The product has a very beautiful bright yellow color, a distinctive aroma of lucuma fruit, a sweet and harmonious taste, and a homogeneous texture.

In this article, the parameters affecting the quality survey process from lucuma fruit may not have been optimized because the added acid concentration is still relatively high. It is recommended to survey parameters with a citric acid concentration of 0.1%.

V. CONCLUSION

The Lucuma jam has a very bright yellow color when the water supplementation ratio is 100%. At a ratio of 70% sugar, 1% pectin, and 0.2% citric acid, the jam product achieves the highest sensory values in terms of color, odor, flavor, and texture with an overall evaluation score of 17.99. The product exhibits brightness of 32.13, a Brix value of 62.66, and a total polyphenol content of 21.53 mgGAE/L.

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