

Processing of premixed puree from *Syzygium cumini* fruit
and Nipa palm syrup (*Nypa fruticans*)

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ARTICLE INFO	ABSTRACT
Research Paper Received: April 02, 2025 Revised: May 17, 2025 Accepted: May 21, 2025 Keywords Nipa palm syrup Processing Puree <i>Syzygium cumini</i> *Corresponding author Nguyen Minh Xuan Hong Email: nmxhong@hcmuaf.edu.vn	This study investigated the processing parameters for the formulation of a premixed puree incorporating <i>Syzygium cumini</i> and Nipa palm syrup, with the objective of developing a natural, nutritionally rich, and palatable product. <i>Syzygium cumini</i>, a fruit abundant in Vietnam's Mekong Delta, is recognized for its high antioxidant and polyphenol content but is under-utilized due to its susceptibility to damage. Nipa palm syrup, a natural sweetener with low-glycemic index, was integrated to enhance both the sensory attributes and nutritional profile of the puree. The research examined key processing factors, including blanching duration, the ratio of <i>Syzygium cumini</i> puree to Nipa palm syrup, pectin concentration, and pasteurization conditions. Experimental results indicated that blanching for 2 min effectively preserved the fruit's characteristic purple color and sensory qualities. A puree formulation with a <i>Syzygium cumini</i>-to-Nipa palm syrup ratio of 7:3 achieved optimal sensory acceptability. The addition of 0.75% pectin resulted in desirable viscosity while maintaining cost efficiency. Pasteurization at 94°C for 4 min was found to ensure microbial stability without inducing significant nutrient degradation. These findings offer a foundation for optimizing processing of a functional puree with enhanced sensory and nutritional properties.

Cited as: Nguyen, Q. D., Dang, D. T., Nguyen, D. V. T., & Nguyen, H. M. X. (2026). Processing of premixed puree from *Syzygium cumini* fruit and Nipa palm syrup (*Nypa fruticans*). *The Journal of Agriculture and Development* 25(3), 116-134.

1. Introduction

The growing awareness of health and nutrition among consumers has led to a substantial increase in demand for functional foods and natural-origin products. This shift has emphasized the necessity of developing food sources rich in

bioactive compounds, particularly antioxidants, which play a crucial role in promoting health and preventing disease. In response to these trends, the movement toward "clean eating and green living" has gained prominence, fostering the production of food items that exhibit high

bioactivity, minimal synthetic additive content, and enhanced environmental sustainability (Siró et al., 2008). Among the diverse native fruit species available in Vietnam, *Syzygium cumini* emerges as a promising yet underutilized resource, warranting further exploration for its potential applications in health-oriented food development.

Syzygium cumini is found in several Vietnamese regions, particularly in the Mekong Delta. In addition to a wealth of vitamins and minerals, it includes a range of bioactive substances, including anthocyanins, flavonoids, tannins, and saponins. These elements serve as antioxidants, strengthen the immune system, and protect against diabetes and other chronic illnesses (Baliga et al., 2011; Sharma et al., 2012). Along with its therapeutic benefits, *Syzygium cumini* has a unique flavor and an attractive deep purple color that make it a great choice for processed goods like juices, jams, syrups, and most notably puree, which can be used as a flexible intermediate ingredient in the food and beverage sector. Previous studies on fruit puree formulations have explored various fruits to develop nutrient-rich products (Kong et al., 2010), but just a few focused on under-utilized species like *Syzygium cumini* (Diep & Ngo, 2023). Moreover, its industrial application has been limited due to its short shelf-life, extremely seasonal character, and lack of standardized processing technologies. This highlights a research gap and emphasizes how important it is to create a suitable puree processing strategy in order to make the most of this local resource. Therefore, the aim of this study was to develop a premixed *Syzygium cumini* puree that preserves the raw material's maximal sensory qualities, nutritional value, and biological activity while

simultaneously increasing the product's shelf life. From a theoretical perspective, the study contributes additional scientific data on the chemical composition and bioactivities of *Syzygium cumini* under Vietnamese conditions, enriching the knowledge on this indigenous species.

Another natural ingredient with high potential in the food industry but limited current utilization is Nipa palm syrup, an extract derived from the male flower stalks or flower clusters of the Nipa palm (*Nypa fruticans*), a typical mangrove species in the Mekong Delta. Nipa palm syrup features a light, unique aroma and is rich in natural sugars (primarily sucrose, glucose, and fructose), minerals (such as potassium and magnesium), and a high level of antioxidants. Compared to refined sugar, Nipa palm syrup has a lower glycemic index and contains numerous health-benefiting compounds, making it a suitable natural sweetener aligned with current healthy eating trends (Teklemariam et al., 2024). The combination of *Syzygium cumini*, rich in anthocyanins and bioactive compounds and Nipa palm syrup, a health-friendly natural sweetener, is expected to result in a puree product with balanced flavor, appealing natural color, high nutritional value, and diverse application potential in the food industry. Using Nipa palm syrup instead of refined sugar is also consistent with the development of clean-label, organic, and functional food products. Practically, the research findings may assist food processing facilities in developing new products from local raw materials, reducing post-harvest losses, enhancing the economic value of regional agricultural products, and meeting modern consumer trends.

2. Materials and Methods

2.1. Sample collection and preparation

Syzygium cumini were purchased from An Giang province. After being purchased, the fruits were selected to remove bruised or rotten and washed to remove dirt.

Nipa palm syrup was purchased at the VietNipa company.

2.2. Chemicals

Plate count agar (standard methods agar) was obtained from HiMedia Laboratories Pvt. Ltd. (India). Sodium hydroxide, potassium chloride, potassium dihydrogen phosphate, sodium

carbonate, sodium chloride, sodium acetate trihydrate, and L(+)-ascorbic acid were obtained from Xilong Scientific Co., Ltd. (China). Hydrochloric acid was obtained from J.T. Baker® (USA). Gallic acid and Folin-Ciocalteu's phenol reagent (2 N) were obtained from Sigma-Aldrich (Merck, Germany). The DPPH (2,2-diphenyl-1-picrylhydrazyl) was obtained from Alfa Aesar (UK). All chemicals are of analytical grade.

2.3. Experimental design

The processing procedure of puree from *Syzygium cumini* and Nipa palm syrup and the experimental design of this study are presented in Figure 1.

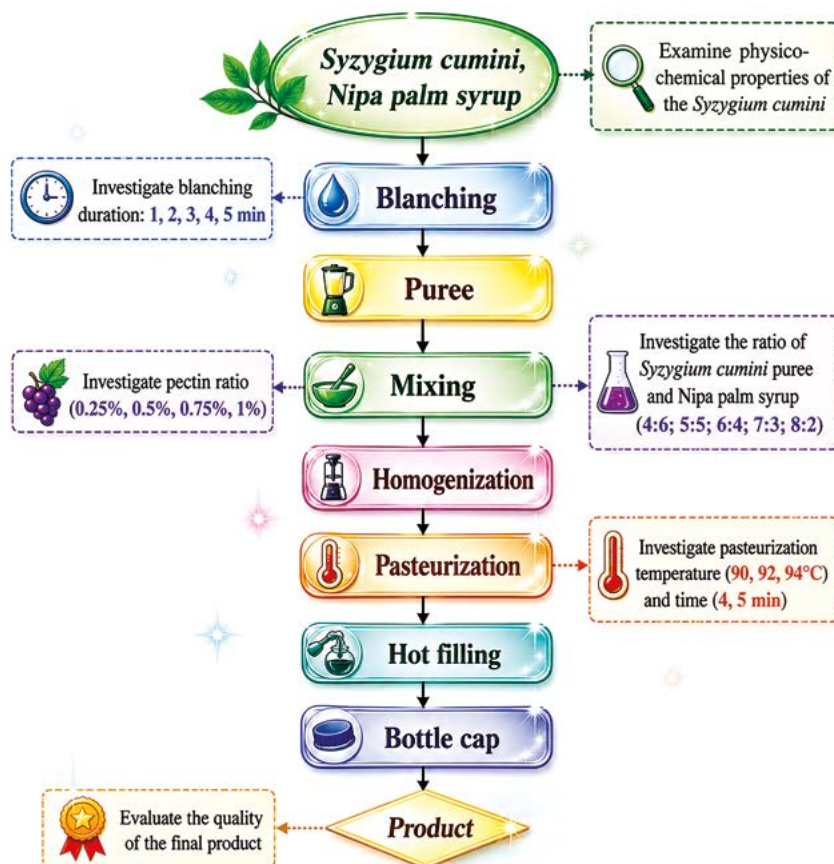


Figure 1. Processing procedure of puree from *Syzygium cumini* and Nipa palm syrup and the experimental design of this study.

2.3.1. Examination of the physicochemical properties of the *Syzygium cumini*

Syzygium cumini fruits were subjected to a washing process using clean water to remove surface contaminants. Damaged, bruised, and improperly ripened fruits were identified based on color assessment and subsequently discarded. The selected fruits were then analyzed for key physicochemical parameters, including moisture content, color, total soluble solids (TSS), acidity, vitamin C, anthocyanin, total phenolics, and antioxidant activity. These analyses were conducted to evaluate the compositional attributes and functional properties of the fruit, providing a basis for further processing and product development.

2.3.2. Investigation of the effect of blanching duration to the quality of puree

The experiment was designed to evaluate the effect of blanching duration on the physicochemical properties of *Syzygium cumini* puree. Blanching was conducted at five different time intervals: 1, 2, 3, 4, and 5 min. Following blanching, the fruits were rapidly cooled using clean water, drained to remove excess moisture, and subsequently processed into puree. The resulting puree samples were analyzed and compared across treatments to determine the optimal blanching time. Evaluations were performed based on recovery efficiency, TSS, total acidity, pH, color, and sensory attributes.

2.3.3. Investigation of the effect ratio of *Syzygium cumini* puree and Nipa palm Syrup on sensory and chemical properties of the product

The experiment was designed to evaluate the effect of varying ratios of *Syzygium cumini* puree

to Nipa palm syrup on the physicochemical and sensory properties of the final product. Five different formulations were prepared with puree-to-syrup ratios of 4:6, 5:5, 6:4, 7:3, and 8:2. Following preparation, the mixtures were homogenized to ensure uniform consistency. The resulting puree samples were then analyzed based on key parameters, including TSS, pH, acidity, and sensory attributes, to determine the optimal formulation.

2.3.4. Investigation of the effect of pectin ratio on the viscosity of the product

In this experiment, pectin was incorporated at varying concentrations of 0, 0.25, 0.5, 0.75, and 1% to assess its effect on the viscosity of the final product. After preparation, the puree samples were subjected to viscosity measurements at intervals of 1 week during 4 weeks to evaluate changes in consistency over time.

2.3.5. Investigation of the effect of pasteurization time and temperature on the quality of the product

In this experiment, the puree underwent heat treatment at six different temperature-time conditions: 90°C for 4 min, 92°C for 4 min, 94°C for 4 min, 90°C for 5 min, 92°C for 5 min, and 94°C for 5 min. After thermal processing, the puree was hot-filled into containers, and the lids were securely sealed to ensure proper preservation. Subsequent analysis was conducted to evaluate physicochemical parameters, followed by the enumeration of aerobic microorganisms after one month to assess microbial stability.

2.3.6. Evaluation of the quality of the final product

Following processing under the established parameters, the product underwent

comprehensive analysis, including chemical composition, microbiological safety, and sensory evaluation. Comparative analysis was conducted with a commercially available product to assess differences in physicochemical properties, microbial stability, and sensory attributes, providing insights into its potential market viability.

2.4. Methods for analysis

2.4.1. Determination of moisture content

Moisture content determination was conducted in accordance with TCVN 10788:2015 using a dryer (UF110, Memmert, Germany). The sample mass was recorded before and after drying at a temperature of 105°C until a constant weight was achieved. Moisture content (MC) was measured according to Equation 1, where m_1 is the sample mass (g) before drying, and m_2 is the sample mass (g) after drying.

$$MC (\%) = (m_1 - m_2) / m_1 \times 100 (\%) \text{ (Equation 1)}$$

2.4.2. Determination of color parameters

The color parameters (L^* , a^* , and b^* values) were measured by using a colorimeter (CR-400, Konica Minolta, Japan) followed principles developed by Hunter & Harold (1987). L^* value corresponds to lightness and varies from 0 to 100, a^* value measures redness when positive and greenness when negative, b^* value means yellowness when positive and blueness when negative.

2.4.3. Determination of pH

The pH determination was conducted using pH meter (pH 7110, WTW, Germany). The principle this method involves the electromotive force generated on the glass surface, which is

uniform and consistent (Harris, 2010). Electrodes on the inside and outside of the glass electrode can exchange with H^+ ions, creating a double layer on the surface of the glass and solution interface. This process generates an electromotive force inside and outside the electrode, which is then translated into the pH scale.

2.4.4. Determination of total titrable acidity

The acidity of the food sample was determined using the titration method described by Paul et al. (2010). A 5 g portion of the sample was mixed thoroughly with purified water in a 100 mL volumetric flask. Subsequently, a 20 mL aliquot from the volumetric flask was transferred to an Erlenmeyer flask, followed by the addition of 1 - 2 drops of 1% phenolphthalein solution as an indicator. The sample was then titrated with 0.1N NaOH solution until a stable pale pink color was observed. This method is based on the principle that the alkaline solution neutralizes all acidic components present in the food sample, with phenolphthalein serving as the visual indicator for endpoint determination. The total acid content (TAC, %) is calculated according to the Equation 2, where 0.0064 is the citric acid conversion index, V is the volume of 0.1 N NaOH used (mL); V_0 is the volume of mixture of sample and water (100 mL), V_1 is the volume of sample aspirated for titration (20 mL), and m is the mass of sample (5 g).

$$TAC (\%) = (0.0064 \times V \times V_0 \times 100) / (V_1 \times m) \text{ (Equation 2)}$$

2.4.5. Determination of total soluble solids (TSS)

TSS were quantified using a refractometer (RSA-BR80, 0-80°Brix, Cole-Parmer, USA) and followed by AOAC method (2005). A drop of the

test sample was placed onto the prism surface, and the prisms were pressed together to ensure proper contact. The eyepiece was adjusted to obtain a sharp dividing line between the dark and light regions of the field of view. This method is based on the principle that light undergoes refraction when transitioning from air, which has a lower refractive index, to a liquid medium with a higher refractive index. The extent of light deflection was measured to determine the solute concentration, allowing for the calculation of its percentage in the sample.

2.4.6. Determination of vitamin C content

Vitamin C content in the sample was determined using the iodine titration method described by Nielsen (2024). A 5 g portion of the sample was weighed and ground in a ceramic mortar with 5 mL of a 5% hydrochloric acid (HCl) solution to facilitate extraction. The ground mixture was then transferred into a volumetric flask containing 50 mL of distilled water and shaken thoroughly until a uniform solution was obtained. A 20 mL aliquot of the prepared solution was subsequently titrated with 0.01 N iodine solution, using starch as an indicator. The titration was carried out until the endpoint, marked by the appearance of a stable blue coloration, was achieved. The method is based on the principle that iodine reacts with vitamin C, allowing for quantification based on the amount of iodine required for complete reaction. The vitamin C content (X, mg/100 g) in the sample was calculated by the Equation 3, where V is the volume of 0.01 N I₂ used (mL), V₁ is the volume of sample (50 mL), V₂ is the volume of aspirated for titration (20 mL), W is the mass of sample for determination (5 g), 0.00088 is the gram of vitamin C in 1 mL of iodine.

$$X = (V * V_1 * 0.00088 * 100) / (V_2 * m) * 100$$

(Equation 3)

2.4.7. Extraction of bioactive compound

Syzygium cumini extracts for anthocyanin, total phenolic content (TPC), antioxidant activity, and total reducing sugar were analysed according to Faria et al. (2011), with some modifications. Aliquot of 10 g of fruit was extracted with 90 mL of 80% methanol for 30 min at room temperature. After that, samples were filtered through the qualitative filter paper.

2.4.8. Determination of anthocyanin content

Anthocyanin content was quantified using the pH differential method described by Lee et al. (2005), with modifications in accordance with TCVN 11028:2015 (MST, 2015a). Briefly, a 1 mL aliquot of the extracted sample was diluted using 0.025 M potassium chloride buffer (pH 1.0) and 0.4 M sodium acetate buffer (pH 4.5). The dilution factor was established when absorbance readings at 520 nm were below 1.2. Absorbance measurements were obtained at 520 and 700 nm using a spectrophotometer (Jenway 7305, Bibby Scientific Ltd., UK) equipped with a calibrated 1 cm cuvette, with distilled water serving as the blank reference. The difference in absorbance between pH values and wavelengths was calculated as in Equation 4.

$$A = (A_{520 \text{ nm}} - A_{700 \text{ nm}})_{\text{pH } 1.0} - (A_{520 \text{ nm}} - A_{700 \text{ nm}})_{\text{pH } 4.5} \quad (4)$$

The concentration (mg/L) of monomeric anthocyanin pigment was calculated following Equation 5, where MW is the molecular weight of cyanidin-3-glucoside (449.2 Da), df is the dilution factor, ϵ is the molar absorptivity derived from a full wavelength scan (26900), l is the standard 1-cm path length.

Monomeric anthocyanin = $(A * MW * df * 1000) / (\epsilon * l)$ (Equation 5).

2.4.9. Determination of total phenolic content (TPC)

The total phenolic content was measured according to Chan et al. (2007) with some modifications. In a test tube, shake well a mixture of 0.3 mL of extract and 1.5 mL of Folin-Ciocalteu reagent 10%, then add 1.2 mL of 7.5% Na_2CO_3 and shake well. After 30 min of reaction at room temperature, the samples were measured for absorption at 765 nm. A calibration curve was built using gallic acid, and the results were displayed as milligrams of gallic acid (GAE) per 100 g of dry matter. The total phenolic content (TPC, mg GAE/100 g DM) was determined by Equation 6, where y is OD of sample, b is OD at intercept point between standard curve with y-axis, V is volume of extracted liquid (mL), DF is dilution factor (mL), a is slope obtained from the most appropriate linear calibration, m is mass of sample, and MC is the moisture content (%).

$$\text{TPC} = ((y - b) * V * \text{DF} * 100) / (a * m * (100 - \text{MC}) * 1000)$$
 (Equation 6)

2.4.10. Determination of antioxidant activity

Antioxidant activity was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, following the method described by Thaipong et al. (2006). A standard curve was constructed using ascorbic acid concentrations ranging from 10 to 80 mg/L. To prepare the DPPH reagent, 3.94 mg (0.0039 g) of DPPH was dissolved in 100 mL of 100% methanol. A 0.2 mL aliquot of diluted sample extract was transferred into a test tube, followed by the addition of 4 mL of 0.1 mM DPPH solution. The mixture was incubated at room temperature in darkness for 30 min. Absorbance measurements were

recorded at 517 nm using a spectrophotometer (Jenway 7305, Bibby Scientific Ltd., UK), with methanol serving as the blank. The total antioxidant capacity (TAC, mg AAE/g) was calculated according to the Equation 7, where x is the concentration from the standard curve (mg AAE/L), V is the volume of the extract used (mL), df is the dilution factor, and m is the mass of extract used (g).

$$\text{TAC} = (x * V * \text{df}) / (m * 1000)$$
 (Equation 7)

2.4.11. Determination of viscosity

Viscosity was measured using a Brookfield RVDV-E viscometer (USA), which operates based on the principle of rotational viscometry followed by Steffe (1996). This method evaluates the liquid's viscosity by assessing the resistance encountered by a submerged spindle rotating at a constant speed. The rotation induces shear stress within the liquid, and the resulting torque is directly proportional to its viscosity. To conduct the measurement, the test sample was poured into an appropriately sized container, ensuring that spindle S04 was immersed to the designated level. The viscometer's control panel was used to set the rotational speed to 30 rpm, a configuration typically adjusted via speed selection buttons or the menu interface. Once the speed setting was confirmed on the display, the spindle was allowed to rotate for approximately 30 - 60 sec to achieve stability. Viscosity readings were then recorded.

2.4.12. Determination of total aerobic microorganisms

Aerobic microorganism enumeration in *Syzygium cumini* puree was performed using the pour plate method, in accordance with TCVN 11039-1:2015 (MST, 2015b). In this procedure, the bacterial cells were mixed with melted agar to ensure uniform distribution throughout the

medium. The mixture was then poured into an empty Petri plate and allowed to solidify. Following incubation, discrete bacterial colonies were observed both on the surface and within the agar matrix. A 1 mL aliquot of the serially diluted liquid sample was thoroughly combined with approximately 15 mL of a specific molten agar medium, maintained at a temperature of 44 - 47°C (not exceeding 50°C), in a Petri plate. The medium was permitted to solidify before undergoing incubation at 37°C for 24 - 48 h. After the incubation period, viable microbial colonies were quantified based on the total count of colony-forming units (CFUs). The number (N) of CFU/g or mL of the test sample is calculated following Equation 8, where C is the sum of colonies on all plates counted, v is the volume applied to each plate, n1 is the number of plates counted at the first dilution; n2 is the number of plates counted at the second dilution, and d is the dilution from which the first count was obtained.

$$N = C/v (n1 + 0.1 n2) * d \text{ (Equation 8)}$$

2.4.13. Sensory evaluation

The final product used the quality assessment method according to the scoring test ranging

from 1 to 5 points with 10 panellists followed by Meilgaard et al. (1999) with some modifications.

2.4.14. Statistical analysis

The experiment was repeated 3 times; the value presented in this article is the mean value. The data was processed, statistically analyzed, and graphed using Minitab Statistical 2021 and Microsoft Excel 2019 software.

3. Results and Discussion

3.1. Chemical properties of *Syzygium cumini*

The chemical composition of *Syzygium cumini* fruit, as presented in Table 1, indicated that it had a high moisture content, making it a juicy fruit. The total soluble solids relate to its high sweetness level, while total acidity gives insight into its tartness. The anthocyanin concentration suggests it's rich in pigments that contribute to its deep purple color. These compounds are also known for their health benefits. Antioxidant activity and total phenolic content reflect its potential in combating oxidative stress, and the presence of vitamin C makes it even more beneficial for immunity and overall wellness.

Table 1. Chemical composition of *Syzygium cumini*

Criteria	Value
Moisture content (%)	78.55 ± 1.17
Total soluble solid (oBrix)	16.67 ± 0.58
Total acidity (%)	1.39 ± 0.04
Anthocyanin (mg/100 g)	7.206 ± 0.17
Antioxidant activity (mg AAE/g)	7.2 ± 0.0003
Vitamin C content (mg/100 g)	9.1 ± 0.5
Total phenolic content (mg/100 g)	84.69 ± 0.42

3.1.1. Effect of blanching duration to the quality of puree

Tables 2 and 3 illustrate significant differences in the physicochemical properties and bioactive compounds of *Syzygium cumini* puree across blanching durations (1 - 5 min).

Table 2. Physicochemical properties of puree at different blanching durations

Blanching duration	Total soluble solids (°Brix)	Total acidity (%)	pH	Puree yield
Control	16.67 ± 0.58 ^b	1.84 ± 0.04 ^a	3.57 ± 0.06 ^{ab}	120.67 ± 1.16 ^a
1 min	16.67 ± 0.58 ^b	1.65 ± 0.04 ^b	3.73 ± 0.06 ^a	110.33 ± 0.58 ^b
2 min	19.33 ± 0.58 ^a	1.62 ± 0.03 ^b	3.67 ± 0.12 ^{ab}	110.00 ± 2.00 ^b
3 min	11.00 ± 1.00 ^c	1.41 ± 0.07 ^c	3.60 ± 0.00 ^{ab}	84.67 ± 1.53 ^c
4 min	9.00 ± 0.00 ^d	1.22 ± 0.07 ^d	3.57 ± 0.06 ^{ab}	73.67 ± 0.58 ^d
5 min	9.00 ± 0.00 ^d	1.12 ± 0.08 ^d	3.50 ± 0.00 ^b	69.67 ± 0.58 ^e
<i>P</i>	< 0.001	< 0.001	< 0.001	< 0.001

^{a,b,c,d,e} Values with different superscript letters within the same column are significantly different ($P < 0.05$).

In Table 2, the 2-min blanching sample exhibited the highest total soluble solids at 19.33 °Brix, compared to 16.67 °Brix (control) and a sharp decline to 9.00 °Brix at 4 - 5 min ($P < 0.05$), indicating optimal sugar retention at 2 min. Total acidity decreased progressively from 1.84% (control) to 1.12% at 5 min, reflecting thermal

degradation of organic acids, as noted by Gao et al. (2000). Puree yield also varied significantly, dropping from 120.67 g (control) to 69.67 g at 5 min, suggesting increased juice loss with longer blanching, consistent with (Rausch & Singh, 2014).

Table 3. Bioactive compounds of different blanching times

Blanching duration	Anthocyanin (mg/100 g)	Total phenolics (mg/100 g)	Antioxidant activity (mg/100 g)
Control	6.79 ± 1.35 ^a	68.12 ± 0.43 ^d	128 ± 0.03 ^b
1 min	6.09 ± 0.10 ^b	92.72 ± 0.28 ^b	133 ± 0.01 ^b
2 min	6.89 ± 2.35 ^a	104.93 ± 0.29 ^a	157 ± 0.01 ^a
3 min	6.23 ± 0.67 ^b	86.66 ± 0.28 ^c	123 ± 0.06 ^b
4 min	5.27 ± 0.34 ^c	46.19 ± 0.35 ^e	93 ± 0.09 ^c
5 min	4.65 ± 1.19 ^d	32.20 ± 0.22 ^f	82 ± 0.18 ^c
<i>P</i>	< 0.001	< 0.001	< 0.001

^{a,b,c,d,e} Values with different superscript letters within the same column are significantly different ($P < 0.05$).

In Table 3, the 2-min blanching sample had the highest anthocyanin content (6.89 mg/100 g), total phenolic content (TPC) (104.93 mg/100 g), and antioxidant activity (157 mg AAE/100 g), outperforming the control and longer blanching

durations ($P < 0.05$). Prolonged blanching (4 - 5 min) reduced anthocyanin to 4.65 mg/100 g and TPC to 32.20 mg/100 g, likely due to thermal instability, as reported by Patras et al. (2010).

Table 4. The color of puree samples at different blanching durations

Blanching duration	L*	a*	b*
Control	31.29 ± 0.98 ^a	18.98 ± 0.54 ^{ab}	-2.75 ± 0.09 ^b
1 min	28.84 ± 0.13 ^b	19.32 ± 2.49 ^{ab}	-1.91 ± 0.49 ^a
2 min	31.38 ± 0.54 ^a	16.33 ± 0.79 ^b	-2.95 ± 0.15 ^b
3 min	31.16 ± 0.61 ^a	19.13 ± 0.23 ^{ab}	-4.82 ± 0.11 ^d
4 min	32.30 ± 1.05 ^a	19.84 ± 0.32 ^a	-4.87 ± 0.25 ^d
5 min	31.22 ± 0.23 ^a	18.72 ± 0.23 ^{ab}	-4.02 ± 0.22 ^c
<i>P</i>	< 0.001	0.03	< 0.001

^{a,b,c,d,ee} Values with different superscript letters within the same column are significantly different ($P < 0.05$).

As presented in Table 4, the blanching had a statistically significant effect on the L*, a*, and b* values of *Syzygium cumini*. It was also observed that increasing the duration of the blanching caused changes in color and intensity, whilst a short blanching duration maintained the natural purple color of the *Syzygium cumini*. Changes in pH altered the stability of anthocyanin, one of the primary pigments responsible for the purple color. The increase of pH (more basic) leads to color degradation, and lower pH means greater stability of anthocyanin. While the 2-min blanched sample had the lowest recovery compared to the rest of the samples, the textual and coloration characteristics of the 2-minute blanched sample reached the general preferences of the sensory panellists. The anthocyanin is the major pigment causing the purple colour in

Syzygium cumini, which also affects the a* value. Higher values of a* yield redder colors, while lower a* values can result in a blue/purplish tint or the color becoming lighter. Also, the b* index (from blue to yellow axis) may also have an effect, but mainly the purple color brilliance. Hence, for the monitoring of the purple coloration of *Syzygium cumini*, it is required to check the a* index changes during processing and storage.

Figure 2 presented the sensory evaluation results for *Syzygium cumini* puree across different blanching durations (0 - 5 min). The 2-min blanching sample consistently received the highest sensory scores across all attributes, outperforming the control (unblanched) and longer blanching durations (3 - 5 min). Overall, results obtained from biological and sensory activities showed that the 2-min blanching

sample retained the characteristic color of the raw material and received the highest score, so

it was chosen as the optimal blanching time to perform the following experiments.

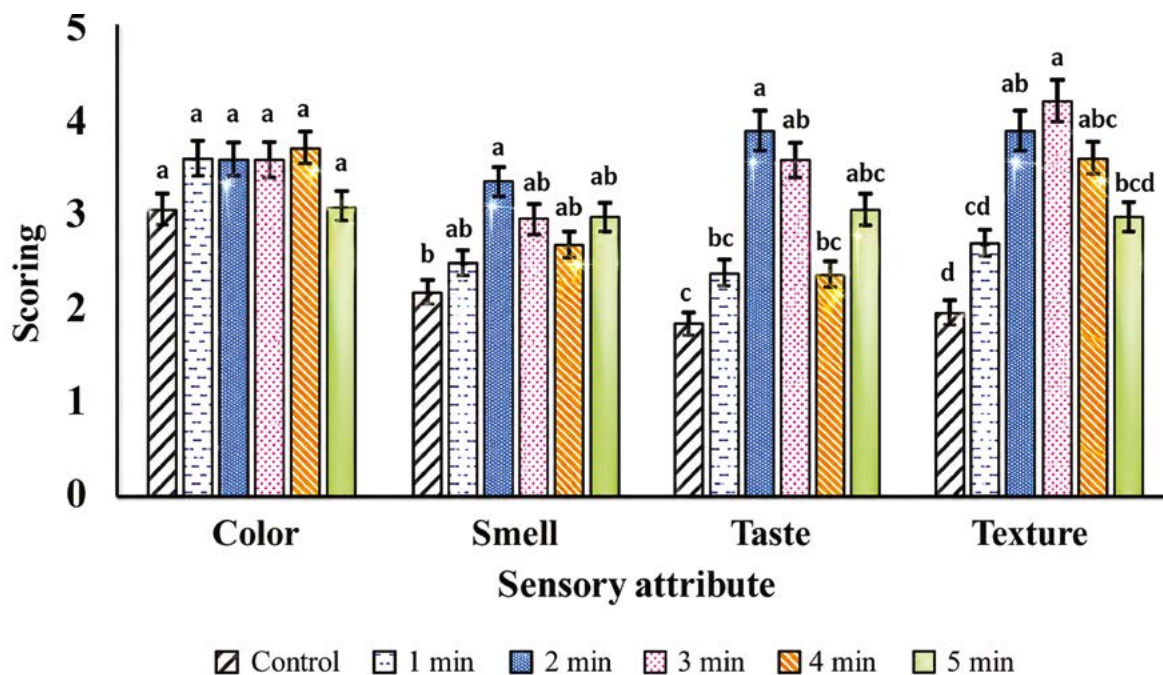


Figure 2. Sensory evaluation of puree samples at different blanching durations.

a,b,c,d Bars with different letters are significantly different from each other at $P < 0.05$.

3.2. Effect of the ratio of *Syzygium cumini* puree and Nipa palm syrup on sensory and chemical properties of the product

Table 5 illustrated the impact of varying *Syzygium cumini* puree to Nipa palm syrup ratios (4:6, 5:5, 6:4, 7:3, 8:2) on the physicochemical and sensory properties of the puree. The 7:3 ratio exhibited the highest sensory acceptability (Figure 5), with a balanced TSS of 29.67 °Brix,

total acidity of 1.88%, and pH of 3.57. This ratio also yielded a high total phenolic content of 96.47 mg/100 g and antioxidant activity of 7.38 mgAAE/g, though slightly lower than the 8:2 ratio (101.12 mg/100 g and 7.57 mg AAE/ g, respectively). The 4:6 and 5:5 ratios, with higher syrup content, showed elevated TSS (47.00 and 41.33 °Brix) but lower acidity (0.90 and 1.06%) and TPC (70.84 and 86.47 mg/100 g), likely due to dilution of fruit-derived bioactive compounds.

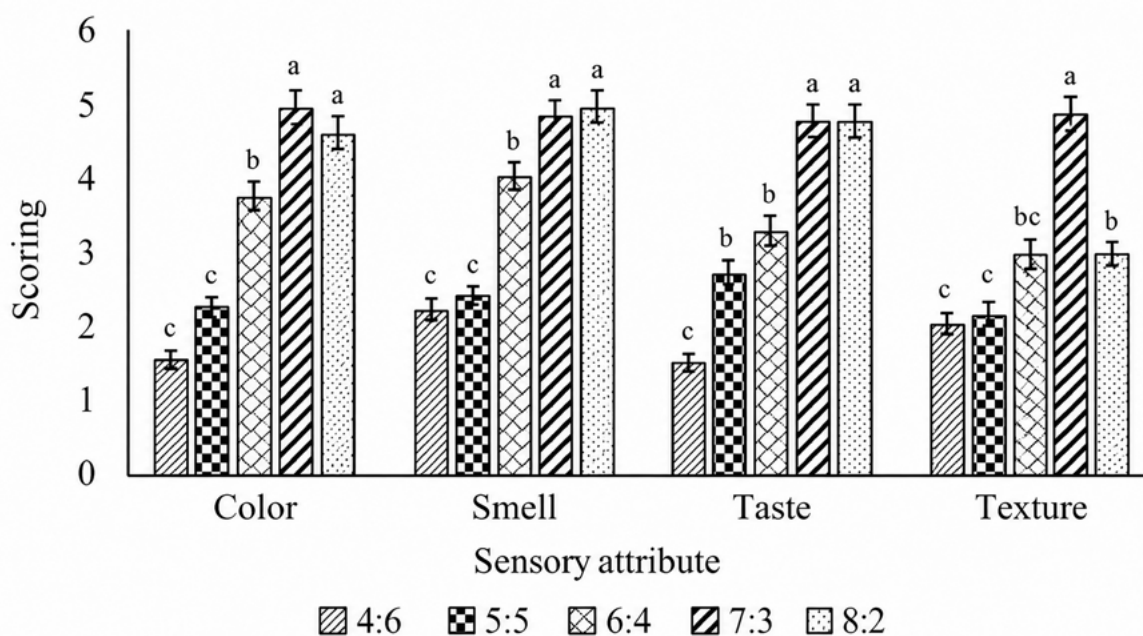
Table 5. Physicochemical properties of each ratio between *Syzygium cumini* puree and Nipa palm Syrup

Ratio	Total soluble solids (°Brix)	Total acidity (%)	pH	Total phenolics (mg/100g)	Antioxidant activity (mg AAE/g)
4:6	47.00 ± 0.00 ^a	0.90 ± 0.07 ^d	3.97 ± 0.06 ^a	70.84 ± 0.16 ^d	6.66 ± 0.03 ^d
5:5	41.33 ± 0.58 ^b	1.06 ± 0.08 ^d	3.83 ± 0.06 ^a	86.47 ± 0.29 ^c	7.20 ± 0.04 ^c
6:4	35.67 ± 0.58 ^c	1.30 ± 0.07 ^c	3.63 ± 0.06 ^b	93.85 ± 0.28 ^b	7.22 ± 0.04 ^c
7:3	29.67 ± 0.58 ^d	1.88 ± 0.03 ^a	3.57 ± 0.06 ^b	96.47 ± 0.22 ^b	7.38 ± 0.06 ^b
8:2	20.67 ± 0.58 ^e	1.64 ± 0.08 ^b	3.53 ± 0.05 ^b	101.12 ± 2.93 ^a	7.57 ± 0.07 ^a
<i>P</i>	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

^{a,b,c,d,e} Values with different superscript letters within the same column are significantly different ($P < 0.05$).

Both ratios 7:3 and 8:2 received high sensory scores without significant differences ($P < 0.05$) (Figure 3). However, the 8:2 ratio, while richest in bioactive compounds, had lower TSS (20.67

°Brix) and less favorable sensory scores, possibly due to excessive tartness. As a result, the ratio 7:3 was chosen as the appropriate mixing ratio for the next experiments.

**Figure 3.** Sensory evaluation of puree samples with different ratios.

^{a, b, c} Bars with different letters are significantly different from each other at $P < 0.05$.

3.3. Effect of pectin ratio on sensory value and viscosity of the product

Table 6 showed that viscosity increased with higher pectin levels. Viscosity decreased over time in all samples, with the most significant

drop by week 4, attributed to structural breakdown and water separation, as noted by Kader et al. (1997). The 0.75% and 1% samples showed the slowest viscosity decline, indicating effective stabilization by pectin, which forms a gel network to retain water.

Table 6. Viscosity (cP) of different ratios of pectin each week

Sample	Week 1	Week 2	Week 3	Week 4	Week 5
Control	2,027 ± 0.58 ^{eB}	2,113 ± 0.00 ^{eA}	1,867 ± 0.00 ^{eC}	1,822 ± 0.58 ^{eC}	1,780 ± 0.00 ^{eD}
0.25%	2,645 ± 0.58 ^{dA}	2,683 ± 0.58 ^{dA}	2,552 ± 0.58 ^{dB}	2,246 ± 0.58 ^{dC}	1,867 ± 0.58 ^{dD}
0.5%	2,965 ± 0.58 ^{cB}	3,073 ± 0.58 ^{cA}	2,940 ± 0.00 ^{cB}	2,642 ± 1.15 ^{cC}	2,480 ± 0.58 ^{cD}
0.75%	4,792 ± 1.00 ^{bB}	5,042 ± 0.58 ^{bA}	4,600 ± 0.58 ^{bC}	4,313 ± 0.00 ^{bD}	4,253 ± 0.00 ^{bE}
1%	5,952 ± 0.58 ^{aA}	5,977 ± 0.58 ^{aA}	5,511 ± 0.58 ^{aB}	5,447 ± 0.00 ^{aC}	5,260 ± 0.00 ^{aD}

a, b, c, d, e Values with different superscript letters within the same column indicate significant difference ($P < 0.05$) between pectin ratios.

A, B, C, D, E Values with different superscript letters within the same row indicate significant difference ($P < 0.05$) between storage time.

Figure 4 revealed that sensory texture scores for the 0.75 and 1% samples were comparable, with no significant difference, suggesting that 0.75% achieves desirable texture while being

more cost-effective. Overall, the 0.75% pectin concentration optimally balances viscosity retention and sensory acceptability while minimizing additive costs.

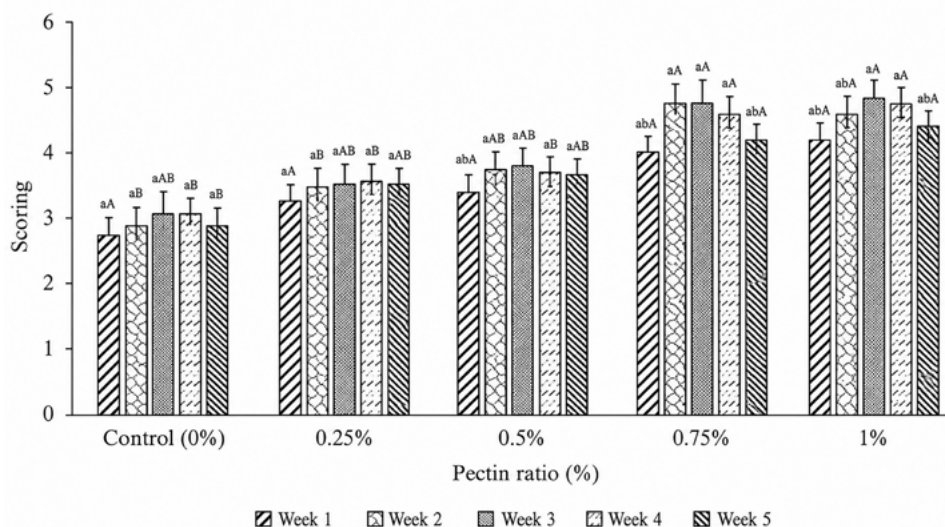


Figure 4. Sensory evaluation of the product texture of samples with different pectin ratios after 5 weeks. Different lowercase letters (a–b) indicate significant differences among storage times within the same pectin ratios, whereas different uppercase letters (A–B) indicate significant differences among pectin concentrations within the same storage time ($P < 0.05$).

3.4. Effect of pasteurization time and temperature on the quality, chemical properties and sensory properties of the product

Tables 7 and 8 compared the physicochemical properties of *Syzygium cumini* puree immediately after pasteurization (Table 7) and after one month of storage (Table 8) across different temperature-time conditions (90°C, 92°C, 94°C for 4 or 5 minutes). In Table 7, the 94°C/5-min condition showed the highest total soluble solids (TSS) at 38 °Brix, pH at 3.90, and lowest acidity at 0.36%,

compared to 90°C/4-min (35 °Brix, pH 3.77, acidity 0.64%) ($P < 0.05$). No layer separation was observed across all conditions, indicating effective stabilization. After one month (Table 8), TSS, pH, and acidity values remained largely unchanged, with 94°C/5-min retaining 38 °Brix, pH 3.90, and 0.36% acidity, and 90°C/4-min at 35 °Brix, pH 3.77, and 0.64% acidity. However, layer separation emerged in some samples, with 90°C/4-min showing 0.2 cm and 94°C/4-min showing none, suggesting better stability at higher temperatures.

Table 7. Physicochemical properties of the product after heat treatment

Time	Temperature	Total soluble solids (°Brix)	pH	Acidity (%)	Layer separation (cm)
4 min	90	35 ^c ± 0.00	3.77 ^b ± 0.06	0.64 ^a ± 0.06	0
	92	35 ^c ± 0.00	3.83 ^{ab} ± 0.06	0.58 ^{ab} ± 0.00	0
	94	35 ^c ± 0.00	3.80 ^{ab} ± 0.00	0.55 ^{ab} ± 0.04	0
5 min	90	35 ^c ± 0.00	3.83 ^{ab} ± 0.06	0.49 ^b ± 0.04	0
	92	36 ^b ± 0.00	3.90 ^a ± 0.00	0.47 ^{bc} ± 0.04	0
	94	38 ^a ± 0.00	3.90 ^a ± 0.00	0.36 ^c ± 0.04	0

^{a, b, c} Values with different superscript letters within the same column are significantly different ($P < 0.05$).

Table 8. Physicochemical properties of the product after 1 month of storage

Time	Temperature	Total soluble solids (°Brix)	pH	Acidity (%)	Layer separation (cm)
4 min	90	35 ^c ± 0.00	3.77 ^b ± 0.00	0.64 ^a ± 0.04	0.2
	92	35 ^c ± 0.00	3.83 ^{ab} ± 0.06	0.58 ^{ab} ± 0.04	0.1
	94	35 ^c ± 0.00	3.80 ^{ab} ± 0.06	0.55 ^{ab} ± 0.04	0
5 min	90	35 ^c ± 0.00	3.83 ^{ab} ± 0.06	0.49 ^b ± 0.04	0.1
	92	36 ^b ± 0.00	3.90 ^a ± 0.06	0.47 ^{bc} ± 0.00	0
	94	38 ^a ± 0.58	3.90 ^a ± 0.06	0.36 ^c ± 0.06	0

^{a, b, c} Values with different superscript letters within the same column are significantly different ($P < 0.05$).

Table 9 presented the total aerobic microorganism counts in *Syzygium cumini* puree after one month of storage under different pasteurization conditions (90, 92, 94°C for 4 or 5 min).

Table 9. Total aerobic microorganisms after 1 month of storage

Time	Temperature	Total aerobic microorganisms (log10 CFU/mL)
4 min	90°C	5.1 ^a ± 0.02
	92°C	3.12 ^b ± 0.02
	94°C	< LOD
5 min	90°C	2.28 ^b ± 0.27
	92°C	1.79 ^b ± 0.18
	94°C	< LOD

LOD: limit of detection. a, bValues with different superscript letters within the same column are significantly different ($P < 0.05$).

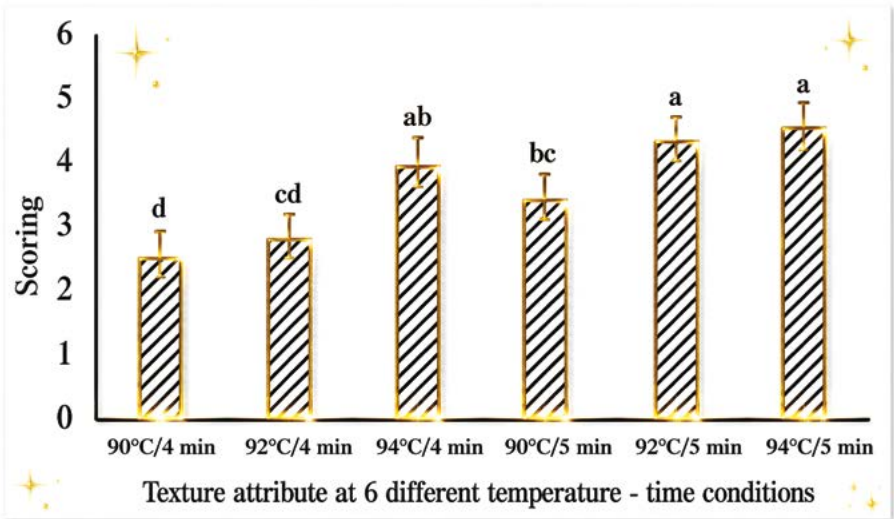


Figure 5. Sensory evaluation of texture at different temperatures and times. ^{a,b,c,d}Bars with different letters are significantly different from each other at $P < 0.05$.

The results showed significant differences in microbial load ($P < 0.05$). The 94°C/4-min and 94°C/5-min conditions achieved zero colony-forming units (CFU/mL), meeting the QCVN 6-2:2010/BYT standard of ≤ 100 CFU/mL for non-alcoholic beverages (MOH, 2010). The sample 94°C/4-min condition is optimal, as it

achieves microbial safety without the extended heating of 5 min, which could degrade bioactive compounds.

For the sensory results of the texture index presented in Figure 5, it also shows that the sensory panellists rated the highest scores for

the 92°C/5 min and 94°C/5 min samples, but the 94°C/4 min sample also gave results with no significant difference. Therefore, choosing the 94°C/4 min sample meets the requirements of food safety and hygiene and helps reduce processing costs.

The sample 94°C/4 min was sent to Eurofins Hai Dang Chromatography to evaluate microbiological indicators, followed by QCVN 6-2:2010/BYT (MOH, 2010). The result after testing was presented in Table 10. After 1 month of storage, no microbial growth was detected.

Table 10. Microbiological indicators of the product after 1 month of storage

No.	Parameters	Unit	<i>Syzygium cumini</i> puree and Nipa Palm Syrup	QCVN 6-2:2010/BYT
1	<i>Clostridium perfringens</i>	Cfu/mL	Not detected	Impossible
2	<i>Staphylococcus aureus</i>	Cfu/mL	Not detected	Impossible
3	<i>Pseudomonas aeruginosa</i>	Cfu/mL	Not detected	Impossible
4	<i>Escherichia coli</i>	Cfu/mL	Not detected	Impossible
5	Fecal streptococci	Cfu/mL	Not detected	Impossible
6	Total aerobic microorganism	Cfu/mL	Not detected	100
7	Coliforms	Cfu/mL	Not detected	10
8	Total yeast and mold	Cfu/mL	Not detected	10

3.5. Evaluation of the quality of the final product

Table 11. Physicochemical and bioactive content of final product

Parameters	Blueberry crush	<i>Syzygium cumini</i> puree with Nipa palm syrup
Moisture content (%)	51.70	66.91
Total soluble solids (oBrix)	45	36
Total acidity (%)	0.40	0.51
Vitamin C (mg/100 g)	9.32	11.1
Anthocyanin (mg/100 g)	45.98	20.82
Total phenolic content (mg/100 g)	66.43	104.46
Antioxidant activity (mg AAE/100 g)	80	149

The final product was compared with a current blueberry product on the market, with results shown in Table 11. The *Syzygium cumini* puree exhibits higher moisture content (66.91 vs. 51.70%), reflecting a less concentrated product, possibly due to minimal processing to retain natural fruit characteristics. Its total soluble solids (°Brix) are lower (36 vs. 45 °Brix), indicating less sugar addition compared to the commercial product. *Syzygium cumini* contains higher vitamin C (11.1 vs. 9.32 mg/100 g), total phenolic content (104.46 vs. 66.43 mg GAE/100 g), and antioxidant activity (149 vs. 80

mg AAE/100 g). The use of Nipa palm syrup, a low-glycemic sweetener, enhances the *Syzygium cumini* puree's health benefits over the blueberry crush sugar-based formulation. These results suggest that the *Syzygium cumini* puree offers a more nutrient-dense, less processed alternative to commercial products.

To accurately assess the nutritional value of *Syzygium cumini* puree, the final product was sent to Eurofins Hai Dang Chromatography for nutritional assessment, the results of which are shown in Table 12.

Table 12. Nutritional value of the final product

No.	Parameters	Unit	Results
1	Dietary fiber	g/100 g	3.09
2	Moisture	%	63.7
3	Ash	g/100 g	1.34
4	Sodium (Na)	mg/kg	1370
5	Carbohydrates (excluding dietary fiber)	g/100 g	30.8
6	Energy value (calculated according to Carbohydrates excluding Dietary fiber)	kcal/100 g	134
7	Protein	g/100 g	1.06
8	Total fat	g/100 g	Not detected
9	Total sugars	g/100 g	16.0

The puree contains 3.09 g/100 g dietary fiber, supporting digestive health and aligning with recommendations for functional foods. Its moisture content (63.7%) reflects a hydrated product, consistent with fruit-based purees, though slightly lower than the 66.91% reported in Table 11, possibly due to analytical variations. The ash content (1.34 g/100 g) indicates a moderate mineral presence, with sodium at 1370 mg/kg (0.137 g/100 g), which is relatively low and suitable for low-sodium diets. Carbohydrates (excluding dietary fiber) are 30.8 g/100 g, contributing to

an energy value of 134 kcal/100 g, making it a moderate-energy food ideal for health-conscious consumers. Protein content is low (1.06 g/100 g), typical for fruit-based products, while total fat is undetectable, enhancing its appeal as a low-fat option. Total sugars (16.0 g/100 g) are moderate, reflecting the use of Nipa palm syrup, a low-glycemic sweetener. This puree offers a balanced nutritional profile with high fiber, low fat, and moderate energy, positioning it as a competitive functional food product.

4. Conclusions

This study developed a processing procedure for premixed puree from *Syzygium cumini* fruit and Nipa palm syrup. The optimal parameters for the process include blanching duration at 2 min, the *Syzygium cumini*-to-Nipa palm syrup ratio of 7:3, the inclusion of 0.75% pectin, and pasteurization at 94°C for 4 min. The product has good sensory attributes with a balanced nutritional profile and the microbial index that meets the requirements of QCVN 6-2:2010/BYT for non-alcoholic beverages (MOH, 2010). These findings provide a foundation for the optimized processing of a functional puree with enhanced sensory and nutritional properties. Further research should be carried out to implement this procedure in an industrial scale.

Conflict of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

We would like to express our sincere gratitude to Nong Lam University, Ho Chi Minh City for funding the project entitled “Processing of premixed puree from *Syzygium cumini* fruit and Nipa palm syrup (*Nypa fruticans*)”, project code CS-SV24-HHTP-06.

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