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The Utilization of *Nypa Fruticans* Palm Sugar (*Gula Apong*) as An Altervative Sweetener in *Kaya* and Its Effects on Physicochemical and Sensory Properties

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Abstract - Coconut jam, or '*Kaya*', is an Asian jam used with toast and sweets. Like jam, *kaya* is loaded in sugar. Palm sugar from *Nypa fruticans* is proposed as an alternative sweetener to regular table sugar that contains no additional nutritional value. *Nypa fruticans* is an underutilised plant in Malaysia that yields palm sugar which has a low glycemic index and is high in vitamins and minerals. This study aims to determine the effect of nypa palm sugar on *kaya*'s physicochemical and sensory attributes. Traditional *kaya* was substituted with nypa palm sugar at 25%, 50%, 75%, and 100%, while traditional *kaya* (no replacement) served as a control. *Kaya* with nypa palm sugar had greater ash, TPC, and TFC than control. Nypa palm sugar has no significant effects on the sensory qualities of *kaya*.

Index Terms - Nypa fruticans palm sugar, Gula Apong; physicochemical, sensory

INTRODUCTION

Coconut Jam, also known as '*Kaya'*, is a well-known jam spread that originates from Asia and is commonly used in Asian breads and pastries. *kaya* is a type of jam that is prepared from coconuts and eggs. It gets its distinctive flavour from the pandan leaf, and sugar is used to sweeten it. It is now widely practised in Malaysia and Singapore, however it was first practised in Hainan, China [1]. It has a flavour that is sweet and may be described as rather creamy, and its colour can range from green to brown, depending on the amount of pandan added [2].

The majority of table spreads, including *kaya*, are high in fat and sugar, and thus high in calories [3]. Nevertheless, growing health awareness has boosted the need for nutritious, safe food. Sugar substitution or replacement is one way to make low-GI, low-calorie, or low-sugar products. In the year 2009, Phang and Chan [3] undertook a study to generate healthier spreads that largely substituted *kaya* with inulin, a prebiotic fructooligosaccharide. Srikaeo and Thongta [4] evaluated sugarcane, palm sugar, coconut sugar, and sorbitol's impacts on wheat starch digestibility and physiochemical characteristics on wheat-based foods. These studies highlighted that palm and coconut sugar could be an alternative healthy sweetener because of their low GI values.

Palm sugar is a sweetener that is extracted from the sap of different palm species, including *Nypa fruticans*, *Arenga pinnata*, *Borassus flabellifer* and *Cocos nucifera* [4]. Locally, Nypa fruticans palm sugar is known as *'Gula apong'* in Sarawak and *'Gula anau'* in Brunei. During the Japanese invasion of Borneo in 1941, it was one of the foods people ate to stay alive [5, 6, 7]. Unlike refined sugar, *gula apong* is natural sugar because it involves minimum processing and no chemicals are used during the process. It contains high amounts of vitamins and minerals and hence its popularity increased as a substitute of white and brown sugar [8, 9].

Therefore, the aim of this study is to develop a palm sugar-based *kaya* spread using *gula apong* and to evaluate the effects of sugar substitution on the physicochemical properties and sensory acceptability of palm sugar-based *kaya*.

MATERIALS AND METHODS

I. Materials and Chemical Reagents

Palm sugar (*Gula apong*) and other ingredients for *kaya* making were purchased from local hypermarket. All chemical reagents used were of analytical grades.

II. Preparation of Control Kaya

The method of preparing *kaya* was adapted and modified from Phang & Chan [3]. Raw materials are represented in percentage (w/w) to assist explanation. Control "*kaya*" was made by stirring together 22% beaten egg, 50% coconut milk, and 24% table sugar (Portion A).

Manual stirring required 5-10 minutes to dissolve and distribute the table sugar. The mixture was heated in a double-boiler at 60°C. The water used to cook the *kaya* was heated using an induction cooker throughout the process, and the water level was kept at least up to the mixture's level in the container. Double boiler heating is preferable to direct heating since it has a slower heating impact and decreases burning risk. Depending on the amount of raw materials utilized, cooking can take several hours. As the temperature climbed, the mixture thickened and turned pale brown from creamy egg-white. Mixtures were stirred constantly for 3 hours at 90°C to avoid egg protein coagulation [10]. Continuous stirring was needed to disperse heat uniformly during cooking; otherwise, localized heat (at the pot's edge and bottom) would coagulate egg proteins.

Refractometer was used to track cooking progress. When the mixture reached 51±1°Brix, 4% table sugar (Portion B) was heated separately in a non-stick skillet until it melted and turned brown. After adding caramel, the mixture turned a golden-brown colour.

The *kaya* mixture was swirled until uniformly coloured. Cooking continued until 57 ±1°Brix to obtain spreadability. As soon as the Brix hit 57°, the *kaya* was hot-filled into pre-sterilized jam glass jars (500 ml) and sealed with fitting lids. The *kaya* was chilled at 6°C after reaching room temperature. Before each sensory examination, the *kaya* was warmed to 25°C.

III. Preparation of Nypa Palm Sugar-Based Kaya

Using a similar procedure, *kaya* substituted with palm sugar was produced by replacing the total sugar. All ingredients were mixed and heated in a double-boiler at 60°C until it reaches 57°Brix.

However, the sugar caramelization step (Portion B) was unnecessary and disregarded in this preparation method as the palm sugar itself gives the brown colour to the *kaya*. Palm-sugar based *kaya* was prepared according to the Table I where table sugar content was substituted with palm sugar at four level of sugar substitution.

TABLE I

FORMULATIONS OF *KAYA*

Ingredients	*Kaya* formulation				
	Control	F1	F2	F3	F4
Coconut Milk	50%	50%	50%	50%	50%
Palm sugar (*Gula Apong*)	-	28%	14%	21%	7%
Table Sugar	28%	-	14%	7%	21%
Fresh eggs	22%	22%	22%	22%	22%

IV. Determination of pH

A calibrated pH metre (HACH®: USA) was used to determine the pH of palm sugar-based *kaya*. First, the pH electrode was cleaned with distilled water and excess water was wiped away with tissue. The pH metre was then calibrated using buffers with pH values of 4 and 7. The pH of the palm sugar-based *kaya* was measured in triplicate after calibration, and the average result was obtained. If the spread is overly thick, a few drops of distilled water can be added.

V. Determination of Moisture Content

Moisture content determination of palm sugar-based *kaya* was carried out by using an air oven (Memmert: Germany). The oven was set to 100°C and all aluminium pans were labelled. Empty aluminum pan was dried at 100°C for 2 hours. Pans were removed after 2 hours and cooled in desiccators. The pan's weight was recorded. A 2.00±0.10g palm sugar-based *kaya* was evenly spread on a pre-weighed aluminium pan and dried for 24 hours at 100°C. The heat was turned off after 24 hours and the pans were cooled in dessicator. The percentage of moisture content was calculated using (1).

$$Moisture\ (\%) = \frac{weight\ of\ moisture\ (g)}{weight\ of\ sample\ (g)} \times 100\% \qquad (1)$$

VI. Determination of Ash Content

The dry ashing method was used to determine the ash content. The ashing crucible was cleaned well before being dried in the oven for at least 1 hour at a temperature of 100.0±0.1°C and cooled in desiccators before use. For the outcome, the weight of the empty crucible with covers was measured and recorded. A total of 2.00±0.10g of material was weighed and recorded in the crucible. They were placed in a muffle furnace (Nabertherm, Germany) for 24 hours at a temperature of 550.0±0.1°C. After that, the sample was placed in desiccators to cool to room temperature. The residual ash was weighed after cooling to room temperature, and the weight was estimated using (2).

$$Ash(\%) = \frac{weight\ of\ ash\ (g)}{weight\ of\ sample\ (g)} \times 100\% \qquad (2)$$

VII. Determination of Crude Protein Content

Kjeldahl technique determined *kaya*'s crude protein. A 2.00±0.05g sample was placed in a digestion tube with two Kjeltabs Cu 3.5 catalyst pills and 12mL of concentrated sulphuric acid. The tubes were gently shook to mix the contents before entering the 420.0±0.1°C digesting procedure, which featured a digester and water aspirator (FOSS: China). The digestive process was hooded. All samples were clear with blue or green solution after 1 hour and 15 minutes of digestion. The digestion tube rack was withdrawn from the digester and cooled to 23.0±3.0°C. Distillation stage requires a digestion tube containing digested sample, 80 mL of deionized water, and 50 mL of 40% sodium hydroxide. On the right side of the distillatory (FOSS: China) is a conical flask containing 25 mL of 4% boric acid (receiver solution) and 3 drops each of methyl red and bromocresol green. A condenser heats the mixture and drips into the receiver solution. Light green indicated alkali-ammonia. The final step in determining crude protein was titration with 0.1 N hydrochloric acid until the distillate turned pale pink. Nitrogen content was calculated from the volume of hydrochloric acid used to titrate the blank and sample. 12mL of concentrated sulphuric acid (H_2SO_4) and two Kjeltabs Cu 3.5 catalyst pills were also analysed. The crude protein was calculated based on (3) and (4).

$$Nitrogen(\%) = \frac{(T - B) \times N \times 0.014}{weight\ of\ sample\ (g)} \times 100 \qquad (3)$$

$$Crude\ protein(\%) = Percentage\ of\ nitrogen(\%) \times F \qquad (4)$$

where,

T = volume of H_2SO_4 used in titration, mL

B = volume of blank titration, mL

N = normality of HCl

F = protein factor, 6.25

VIII. Determination of Crude Fat Content

Palm sugar-based *kaya*'s crude fat content was extracted using Soxhlet method. Before analysis, extraction cups are cleaned and dried overnight at 102.0±3.0°C. A 2.00±0.01g pre-dried sample was weighed onto filter paper and wrapped in cellulose thimble. The adapter was used to lift the thimbles from the holder. The Soxtec Extraction System (Foss: China) was used to start the process after adding 70 mL of petroleum ether to the extraction cups. Thimble and extraction cup were placed on a condenser-connected heater. Continuous boiling of sample was carried out for 15 minutes as the condenser valve is opened. After 30 minutes of rinsing, thimbles were recovered for 10 minutes. Then, thimbles were pre-dried for 5 minutes to evaporate excess solvent. Extraction cups were dried at 102.0±3.0°C for at least two hours before being weighed. Equation (5) was used to calculate *kaya*'s fat content.

$$Crude\ Fat\ (\%) = \frac{Weight\ of\ fat}{Weight\ of\ sample} \times 100\% \qquad (5)$$

IX. Determination of Calorie Content

Using a bomb calorimeter, the calorie content of palm sugar-based *kaya* was determined (IKA: Germany). Analytical balance was used to weigh 2.0 ±0.01g of sample into Acetobutyrate capsules. It was placed in a nickel dish on the decomposition vessel. Cotton thread should touch capsules to ensure sample ignition. The entire decomposition vessel was filled with oxygen. Subsequently, the decomposition vessel was placed in the bomb calorimeter. Aquapro solution was added to the bomb calorimeter's compartment. After closing the vessel, analysis will begin automatically. The unit displays and records the combustion result.

X. Determination of Carbohydrate Content

Carbohydrate content in each sample was calculated by subtracting the sum (%) of moisture, ash, protein and fat from 100% as (6).

$$Carbohydrate(\%) = 100\% - Moisture(\%) - Ash\ (\%) - \ Protein\ (\%) - \ Fat\ (\%) \qquad (6)$$

XI. Determination of Mineral Profile

Inductive couple plasma-optical emission spectrometry (ICP-OES, Perkin-Elmer model optima 3300 Dv, Norwalk, CT, USA) was used to determine the minerals potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), phosphorus (P), iodine (I), chromium (Cr), and silica (Si) according to AOAC method.

XII. Determination of Total Phenolic Content (TPC) and Total Flavonoid Content (TFC)

Folin-Ciocalteu was used to determine TPC [11]. 0.3 mL of *kaya* was mixed with Folin-Ciocalteu reagent (1:9 with water) and 1.2 mL of 7.5% sodium carbonate solution (Sigma-Aldrich). After 30 minutes in the dark, the absorbance at 725 nm was measured with a Shimadzu UV-2100 spectrophotometer. The TPC was expressed as mg GE/g sample dry weight.

Woisky and Salatino [12] determined TFC. 0.5 mL of *kaya* was mixed with 95% ethanol (Sigma-Aldrich). After adding 0.1 mL of 10% aluminium chloride, 0.1 mL of 1 M potassium acetate, and 2.8 mL of distilled water, the mixture was kept at room temperature for 30 minutes. Using a Shimadzu UV-2100 spectrophotometer, 415 nm absorbance was measured. The TFC was mg RE/100 g, (dry weight).

XIII. Sensory Evaluation

Affective testing, or known as hedonic test method, was used to quantify the degree of liking or disliking of a product. In this study, the sensory properties of palm sugar-based *kaya* were determined using hedonic test method. About 30 untrained panellists were randomly selected to complete the sensory evaluation. Palm sugar-based *kaya* was served along with the bread and deionized water was used for the rinsing of panellist's mouth. The palm sugar-based *kaya* was evaluated in terms of the colour, sweetness, spreadability, aroma, and overall acceptability. The scales of rating range from dislike extremely (1) to like extremely (9).

XIV. Statistical Analysis

SPSS Version 23 (Statistical Package for the Social Science, IBM: United States) was employed to examine all data collected in the physicochemical (except mineral, TPC and TFC) and sensory analysis. Complete block one-way analysis of variance (ANOVA) was used to determine the significant difference of the mean values. The Tukey's test is conducted to determine if there is any significant difference at the level of p-value < 0.05.

RESULTS AND DISCUSSIONS

I. Physicochemical Properties

Table II evaluates the effect of palm sugar substitution in *kaya* on pH, moisture, ash, crude protein, crude fat, carbohydrate and calorie content.

All *kaya* formulations had a mild acidic pH ranging from 5.81 to 5.84. The control sample had the highest pH value, but there were no significant differences in pH between the five *kaya* formulations (p>0.05). Lower pH of palm-sugar based *kaya* (F1 – F4) may be attributed to the presence of organic acid in the nypa palm sap [13, 8]. Moreover, Naknean and Meenune [14] postulated that palm syrup (*Gula apong*) preparation concentrated organic acids, lowering the finished syrup's pH. The Maillard reaction can also produce some organic acids, which might affect the acidity of the resulting syrup [15, 16].

No significant differences were observed in moisture content of *kaya*. However, a slight increase in moisture was observed in all palm sugar-based *kaya* relative to the control *kaya*. It could be owing to the fact that the gula apong is in a liquid state which has more water than granulated sugar. Generally, IMF products has a moisture content around 20% to 50% [17]. Hence, it can be concluded that all formulations of *kaya* fall within the IMF range and may have a several-month shelf life.

Ash levels in palm sugar-based *kaya* formulations (F1-F4) were found to be substantially higher than in the control sample. The ash content of a food is a measure of the total amount of minerals present [18]. This finding is in agreement with the elemental composition of *kaya* as shown in Table III.

TABLE II

PHYSICOCHEMICAL PROPERTIES OF *KAYA*

Analysis	Control	F1	F2	F3	F4
pH	5.84 ± 1.42^a	5.78 ± 1.12^a	5.81 ± 0.98^a	5.79 ± 1.43^a	5.83 ± 1.65^a
Moisture (%)	25.5 ± 1.12^a	26.83 ± 1.12^a	26.21 ± 2.17^a	26.59 ± 0.88^a	25.9 ± 1.21^a
Ash (%)	0.80 ± 2.32^b	1.70 ± 1.76^a	1.10 ± 0.68^a	1.20 ± 0.91^a	1.10 ± 1.32^a
Crude Protein (%)	2.11 ± 1.76^a	2.27 ± 2.21^a	2.20 ± 1.11^a	2.24 ± 1.23^a	2.14 ± 0.89^a
Crude Fat (%)	1.59 ± 1.78^a	1.27 ± 1.21^a	1.31 ± 1.65^a	1.33 ± 1.42^a	1.18 ± 0.98^a
Carbohydrate (%)	70.00 ± 2.21^a	68.13 ± 3.23^a	69.79 ± 1.89^a	67.55 ± 4.42^a	67.25 ± 5.55^a
Calorie (J/g)	11460 ± 1.12^a	11325 ± 1.22^a	12018 ± 2.33^a	11390 ± 3.21^a	11106 ± 1.34^a

F1: 100% palm sugar/0% table sugar, F2: 50% palm sugar/50% table sugar, F3: 75% palm sugar/25% table sugar, F4: 25% palm sugar/75% table sugar

Means ± SD in the same column with the same letters are not significantly different (P ≤ 0.05).

Expressed in mg/kg (dry weight), F1 has shown the highest content of all minerals determined in this study. K (5400 – 12500 mg/kg) and Na (860-4500 mg/kg) were the major minerals observed in palm sugar-based *kaya*. Supported by Saengkrajang et al. [8], both K and Na was the most abundant minerals in nypa palm syrup. Since negatively charged soil particles absorb K and Na, they are readily available to plant roots [19].

TABLE III

MINERAL PROFILES OF *KAYA*

Minerals (mg/kg)	Control	F1	F2	F3	F4
Potassium, K	ND	12500	9509	10800	5400
Sodium, Na	ND	4500	3390	4032	860
Phosphorus, P	ND	710	588	650	232
Magnesium, Mg	ND	332	180	270	86
Silica, Si	ND	422	211	390	78
Calcium, Ca	ND	55	14	30	8
Iron, Fe	ND	21	4	12	ND
Copper, Cu	ND	2	0.2	0.7	ND
Iodine, I	ND	3	0.5	1.5	ND
Manganese, Mn	ND	2	0.6	1.2	ND
Zinc, Zn	ND	2	0.5	1.2	ND
Chromium, Cr	ND	0.1	ND	0.1	ND

F1: 100% palm sugar/0% table sugar, F2: 50% palm sugar/50% table sugar, F3: 75% palm sugar/25% table sugar, F4: 25% palm sugar/75% table sugar

ND: Not detected

According to Reid and Hayes [20], K is the most abundant cation in plant cells and required for growth and can be found extensively in nypa palm syrup. Furthermore, the chemical (e.g., surface charge and pH) and physical (e.g., structure and texture) soil qualities, ambient growth circumstances, season, and plant metabolism influence the nutrient availability on the root surface [19]. Naturally, nypa palm is a mangrove palm that grows in mangroves and somewhat saline environments [21, 22]. As a result, nypa palm sap has more minerals than coconut and palmyra palm.

Crude protein content in all samples were in range of 2.11 – 2.27. The protein content of all palm sugar-based *kaya* was slightly higher than that of control sample which may be attributed to the protein present in nypa palm sugar. Agreeable with Saengkrajang et al. [8], protein content of nypa palm syrup collected from different areas, ranging from 2.0 – 2.9% (w/w). This finding is also supported by the fact that other than taste and calories, refined sugar or white sugar provides no further benefits [3].

No significant differences were observed in crude fat content, indicating that palm sugar substitution has no effect on the fat content. Saengkrajang et al. [8] and Phetrit et al. [9] suggested negligible fat was found in nypa syrup.

The control sample had the highest carbohydrate content (70 g/100 g). In all formulations, no significant differences were observed. The use of refined sugar or palm sugar as a primary raw component in *kaya* production contributed to the *kaya*'s high carbohydrate content [8, 9]

The highest calorie was found in F2 (12018 J/g) followed by control (11460 J/g), F3 (11390 J/g), F1 (11325 J/g) and F4 (11106 J/g). No significant differences were recorded. The variation in energy was presumably linked to the type of sugar and its individual concentration because all of the samples had similar concentrations of the overall sweetener utilized.

Full substitution (F1) of sugar with nypa palm sugar has produced *kaya* with the highest TPC and TFC values, 40.2 mg GE/100 g and 26.1 mg RE/100 g, respectively. The presence of endogenous polyphenols in nypa palm sap and syrup explains the high concentration of TPC and TFC detected in both [8, 9, 24]. Table IV indicated that the more palm sugar used, the higher TPC and TFC was detected in *kaya*.

TABLE IV

TPC AND TFC IN *KAYA*

Analysis	Control	F1	F2	F3	F4
TPC mg GE/100 g	ND	40.2	15.4	31.4	8.6
TFC mg RE/100 g	ND	26.1	6.6	13.5	1.2

F1: 100% palm sugar/0% table sugar, F2: 50% palm sugar/50% table sugar, F3: 75% palm sugar/25% table sugar, F4: 25% palm sugar/75% table sugar

ND: Not detected

II. Sensory Properties

The substitution of 50% (F2) table sugar with *gula apong* resulted in the best spreadability (7.1), indicating that the equal concentration of sweetener had a positive effect on the ability to spread. Most panellists preferred F2 to have the best sweetness (6.6). It stipulated that the combination of 50-50% concentration of *gula apong* and table sugar had a synergistic effect on the sweetness of *kaya*. The control sample (6.3) was preferred by the panellists as the best *kaya* for its colour. The darker colour of *gula apong* appeared to have a negative effect on the colour of *kaya*, indicating that the majority of the panellists preferred a lighter brown colour. Panellists preferred F4 for its aroma properties the most (6.2). According Prasad et al. [25], the presence of phytochemicals in nypa palm syrup may be associated with the syrup's flavour qualities (e.g., floral and caramel fragrance). For overall acceptability, F2 was preferred the most (6.2). The balance concentration of table sugar and *gula apong* resulted in acceptable sensory quality as a whole. Generally, panellists discovered that all samples had similar spreadability, sweetness, colour, aroma and overall acceptability levels, with no significant differences (p>0.05) amongst them (Table V). It presumably suggests that utilization of nypa palm sugar contributed no direct effect on those criteria, implying that such sweetener did not reduce the sensory quality of *kaya*.

TABLE IV

CONSUMER'S PREFERENCES TOWARDS SENSORY PROPERTIES OF *KAYA*

Formulas	Control	F1	F2	F3	F4
Spreadability	6.80 ± 1.40[a]	7.00 ± 2.05[a]	7.10 ± 1.20[a]	6.70 ± 1.77[a]	7.00 ± 1.41[a]
Sweetness	5.20 ± 1.55[a]	5.50 ± 2.64[a]	6.60 ± 0.97[a]	6.10 ± 0.88[a]	6.20 ± 1.40[a]
Colour	6.30 ± 2.21[a]	5.50 ± 2.64[a]	6.00 ± 1.41[a]	5.40 ± 1.78[a]	5.70 ± 2.45[a]
Aroma	5.90 ± 1.73[a]	5.80 ± 2.66[a]	6.10 ± 1.29[a]	5.20 ± 1.81[a]	6.20 ± 2.04[a]
Overall Acceptabiliy	5.70 ± 1.95[a]	5.90 ± 2.56[a]	6.20 ± 1.40[a]	5.80 ± 0.92[a]	6.10 ± 1.70[a]

F1: 100% palm sugar/0% table sugar, F2: 50% palm sugar/50% table sugar, F3: 75% palm sugar/25% table sugar, F4: 25% palm sugar/75% table sugar

Means ± SD in the same column with the same letters are not significantly different ($P \leq 0.05$).

CONCLUSIONS

In the nutshell, utilization of nypa palm sugar (*Gula apong*) in *kaya* had no significant effect on physicochemical properties such as pH, moisture, crude protein, crude fat, carbohydrate and calorie content. Meanwhile, due to the presence of minerals in *gula apong*, the ash content of treated samples (F1 – F4) was found to be substantially greater than the control sample. Furthermore, the incorporation of nypa palm sugar in *kaya* also resulted in increased TPC and TFC values. *Gula apong* has no significant effects on the sensory qualities of *kaya*.

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