Food Research 9 (1) : 272 - 281 (February 2025)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Characterization of meringue formulated with different palm sugar substitutes

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Article history:
Received: 7 July 2023
Received in revised form: 3 October 2023
Accepted: 20 August 2024
Available Online: 22 February 2025

Keywords:
Egg white,
Meringue,
Coconut palm sugar,
Nypa palm sugar

DOI:
https://doi.org/10.26656/fr.2017.9(1).189

Abstract

Sugar acts as a stabilizing agent by binding with the water and giving a stable shape to the meringue. The addition of sugar is the critical point in the production of meringue, as it is expected to increase the temperature of protein denaturation, as well as to reduce the drainage of foam which indicates high stability. This study aimed to determine the effects of palm sugar substitution on the total soluble solids, and physicochemical (i.e., pH, moisture, specific volume, hardness, colour profiles), functional (i.e., foam capacity and stability), rheological (i.e., viscosity) and sensorial (i.e., colour, smoothness, aroma, hardness, adhesiveness, sweetness, overall acceptability) properties of whipped meringue and/or baked meringues. According to the results, substituting 70% coconut palm sugar (CPS) in meringue formulation significantly increased ($P<0.05$) its foam capacity (%). Following that, the substitution of 70% nypa palm sugar (NPS) significantly increased ($P<0.05$) the moisture, foam capacity (%), and hardness of meringue cookies. The total soluble solids, pH, and colour (lightness) of coconut and nypa palm sugar meringues, as well as the specific volume and colour (lightness) of both meringue cookies, have decreased significantly compared to the control. Additionally, nypa palm sugar meringue has significantly decreased ($P<0.05$) its viscosity and foam stability (%). For overall acceptability, NPS50% meringue cookies have the highest overall acceptability (7.63), followed by NPS70% (7.60) and CPS50% (7.10) with no significant differences ($P>0.05$) to each other in most of their physicochemical, rheological, and functional qualities but majorly showed significant differences to control.

1. Introduction

Meringue is a popular confectionary product made of egg white foam and sugar. It is made by incorporating air into a beaten egg white together with white sugar (WS) as a stabilizer (Lekjing *et al*., 2022). In meringue making, typically, refined white granulated sugar or sucrose is the most common one to be utilized. However, it is a simple carbohydrate with no beneficial health effects, although it does improve consumer perception. Without sucrose, the meringue will lose some of its properties such as foaming capacity and foaming stability. However, sucrose concentration in meringue is very high. For traditional meringue, a 1:2 or 1:3 protein-to-sugar ratio is required. Consumers are moving towards products and/or sweeteners with a lower glycemic index (GI), and better nutritional properties.

Palm sugars are natural sweeteners that can be derived from the saps of palm trees. Coconut palm sugar (gula melaka) and nypa palm sugar (gula apong) are not uncommon to Malaysians. Both have been applied in a variety of food products such as ice cream, cake, traditional 'kuih' and many more. Furthermore, the effects of palm sugar variation on the properties of egg whites are not yet being studied. These explain why the need to find alternative sweeteners has become even more pertinent (O'Niones, 2014).

Several parameters, such as pH, temperature, heat treatment, egg ageing, protein content, acid addition, and salt addition, have an impact on the properties of egg whites (Yang and Foegeding, 2010; Luo *et al*., 2020). In previous studies, the substitution of palm sugars in food products such as kaya jam (Mohd Syafiq *et al*., 2022), chocolate (Nurhayati *et al*., 2022), chocolate cake (Saputro *et al*., 2018), carrot cake (Tai, 2020), and bread (Whelan *et al*., 2008) could have different effects on physicochemical, nutritional, and sensorial properties. For instance, palm sugar substitution may increase moisture content, cause food colour to be darker, yield

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

tougher texture, improve nutritional values and have better sensorial properties (Saputro *et al*., 2018; Tai *et al*., 2021; Nurhayati *et al*., 2022). Additionally, when palm sugars are applied to food products, the glycemic index and antioxidant activity significantly decrease and increase, respectively (Whelan *et al*., 2008; Tai *et al*., 2021). Furthermore, Prijono and Rachmatika (2020) reported that the composition of coconut palm sugar sap in terms of protein, carbohydrate, and fats composition were 1.61%, 89.40% and 0.76%, respectively whereas for nypa palm sugar sap were 1.70%, 86.12% and 0.70%, respectively. The difference in nutritional composition will influence the physicochemical and functional properties of meringue differently.

In this study, white sugar in meringue was substituted with each coconut and nypa palm sugar at two different concentrations [Control (100%WS), CPS50%, CPS70%, NPS50%, NPS70%]. Hence, the objective of this study is to determine the effects of palm sugar substitution on the total soluble solids, physicochemical (i.e., pH, moisture, specific volume, hardness, colour profiles), functional (i.e., foam capacity and stability), rheological (viscosity) and sensorial properties (i.e., colour, smoothness, aroma, hardness, adhesiveness, sweetness, overall acceptability) of the whipped meringues and/or baked meringues.

2. Materials and methods

2.1 Materials and tools

The ingredients for making meringue and meringue cookies including egg white, white sugar, salt, and vanilla extract were purchased from a local market in Shah Alam, Malaysia. Coconut palm sugar (The Great Ingredients) and nypa palm sugar (CocoWorld) in granulated form were obtained from an online shopping platform. The palm sugar should be from the same brand throughout the entire analysis for uniformity and precise results.

2.2 Preparation of meringue and meringue cookies

All meringue and meringue cookie formulations as shown in Table 1 were made using the Swiss meringue method (Wierenga *et al*., 2012). It involves heating the mixture of egg white, sugar(s) and other ingredients using the Bain-marie method to dissolve the coarse sugar granular for better foam stability (Li *et al*., 2019). After heating, the meringue was whipped with a stand mixer (1000 W, 5L- Johnsonlux) at low speed for the first 2 mins, then the speed to high was increased gradually for another 6-15 mins or until medium peak was formed (Table 2). An additional 2 mins of whipping for 70% nypa palm sugar meringue is required after storing it in the freezer for 30 mins in a metal bowl. The meringues were piped and then baked at 105℃ until fully cooked [1 hr to 1 hr and 20 mins] (Table 2). Figure 1 shows the meringue and meringue cookies for Control, F1, F2, F3, and F4.

Table 2. Beating and baking time of each formulation.

Formulations	Beating time to reach medium peak (min)	Baking time at 105℃ (min)
Control	8.00	60.00
F1	8.00	60.00
F2	9.00	65.00
F3	14.00	70.00
F4	17.00	75.00

Control: 100%WS, F1: 50%CPS, F2: 70%CPS, F3: 50%NPS, F4: 70%NPS, WS: White sugar, CPS: Coconut palm sugar, NPS: Nypa palm sugar.

2.3 Physiochemical properties

2.3.1 Total soluble solids

The total soluble solid (TSS) (°Brix) of unwhipped meringue was tested using a digital Abbe refractometer (Muhammad *et al*., 2021). A drop of cooled and concentrated solution was placed on the refractometer and readings were recorded.

2.3.2 pH

A determination of pH was done to determine the level of acidity of whipped meringue (Muhammad *et al*., 2021). The pH meter was calibrated first with pH buffers 4 and 7. Then, the pH was determined by submerging the pH meter probe into the meringue and readings were recorded.

2.3.3 Moisture

The moisture content of whipped meringue was determined using the oven-drying method for each formulation (Xu *et al*., 2017). The percentage of

Table 1. Formulations of meringue.

Ingredients	Control	F1	F2	F3	F4
White sugar	100 g	50 g	30 g	50 g	30 g
Palm sugar	0 g	CPS: 50 g	CPS: 70 g	NPS: 50 g	NPS: 70 g
Egg white	88 g	88 g	88 g	88 g	88 g
Salt	0.3 g	0.3 g	0.3 g	0.3 g	0.3 g
Vanilla extract	1 mL	1 mL	1 mL	1 mL	1 mL

Control: 100%WS, F1: 50%CPS, F2: 70%CPS, F3: 50%NPS, F4: 70%NPS, WS: White sugar, CPS: Coconut palm sugar, NPS: Nypa palm sugar.

https://doi.org/10.26656/fr.2017.9(1).189

Figure 1. Meringue (M) and meringue cookies (MC) for Control, F1, F2, F3, and F4. Control: 100%WS, F1: 50%CPS, F2: 70%CPS, F3: 50%NPS, F4: 70%NPS, WS: White sugar, CPS: Coconut palm sugar, NPS: Nypa palm sugar.

moisture was then calculated using the following formula:

$$Moisture\ (\%) = \frac{(\text{Wt of wet sample + pan + lid}) - (\text{Wt of dried sample + pan + lid})}{(\text{Wt of wet sample + pan + lid}) - (\text{Wt of pan + lid})} \times 100$$

2.3.4 Colour profiles

The colour measurement of whipped meringue and meringue cookies was evident based on CIE L*, a*, and b* colour systems using a colourimeter (CR-400 Chroma Meter) (Naknean *et al*., 2013). Parameter L* refers to the lightness of the samples, ranging from black (L = 0) to white (L = 100). For parameter a* (chroma), the negative value indicates green and a positive one indicates red-purple colour whereas the positive value of parameter b* (hue) indicates yellow while the negative value indicates blue colour (Budžaki *et al*., 2014).

2.3.5 Specific volume

Specific volume of meringue cookies was calculated by dividing volume by weight values (Shittu *et al*., 2007; Laukova *et al*., 2016). The constant weight reached was recorded for each consecutive measurement. The meringue volume was immediately determined after baking by using the green bean displacement method. The volume and specific volume of the sample were calculated as follows:

$W_{seed} = W_{total} - W_{sample} - W_{container}$

$V_{seed} = W_{seed}/P_{seed}$

$V_{sample} = V_{container} - V_{seed}$

Specific volume (cm^3/g) = V_{sample}/ W_{sample}

Where W = weight (kg), V = volume (m^3) and P = density (kg/m^3)

2.3.6 Hardness

The texture of meringue cookies was determined by a cutting/ shearing test (Yuceer and Asik, 2020) using a texture analyzer. A standard blade fixture probe (HDP/ BS) was used to cut or shear the test sample that was placed on a base, and the force (g) required to cut the cookies into two parts in a specific amount of time and under defined conditions, was measured and used as an index of hardness.

2.4 Functional properties

2.4.1 Foam capacity and stability

The volume of foam was calculated using the volume formula of a cylinder, V = 2πrh where 'r' was the radius (cm) of cylinder and 'h' was the levelled height (cm) of the meringue. Then, as in Li *et al*. (2019) study, a modified version of Phillips *et al*. (1990) foam stability method was used which after 20 mL of meringue solution was whipped, it was transferred to a 100 mL measuring cylinder and covered with plastic wrap. These were then stored at room temperature and liquid drainage was recorded at 30 s, 60 mins, 120 mins and 180 mins time intervals. The following equations derived from O'Niones's study (2014) for foam capacity, and Lomakina and Mikova's study (2006) for foam stability were used:

FC (%) = [(FV – ILV) / ILV] × 100%

FS (%) = [(ILV − DV) / ILV] × 100%

DV (mL) = LVM – LVS

Where FV = final volume of foam, ILV = volume of the initial liquid phase, DV = volume of drainage, LVM

https://doi.org/10.26656/fr.2017.9(1).189

= volume of the liquid phase at t = 60/120/160 mins after foaming was finished and LVS = volume of the liquid phase at t = 30 s after foaming was finished

2.5 Rheological property

2.5.1 Viscosity

Viscosity (cP or mPa*s) was calculated using the method described by Psimouli and Oreopoulou (2012) and O'Niones (2014). Using a Brookfield viscometer (RVT 115V), all meringue formulations were analyzed using spindle no. 4 at 12 rpm. The result taken was in Dial Reading and was converted to viscosity using the following equation:

Viscosity (centipoise) = Dial reading (average) × factor

2.6 Sensory properties

Sensory evaluation was conducted at the sensory laboratory of the Faculty of Applied Science in UiTM Shah Alam. Meringue cookies were evaluated in terms of appearance (colour, smoothness), aroma, texture (hardness, adhesiveness), and overall acceptability by using the 9-point hedonic scale method (Laukova *et al*., 2016). The evaluation was achieved by selecting 30 panellists among male and female UiTM students aged from 19-25, to assess the degree of acceptability. Samples that have been coded were packed in enclosed plastic containers accordingly prior to serving. From the result obtained, the average score by panellists for each sample acceptability was calculated.

2.7 Statistical analysis

The results of all experiments were calculated, and an analysis of variance (One way ANOVA) was performed on each characteristic using the SPSS Version 26. If the significance is found ($P<0.05$) when comparing means, the Least Significant Differences were determined using the Tukey HSD test.

3. Results and discussion

3.1 Physiochemical properties

3.1.1 Total soluble solids

Table 3 shows that every sample was statistically different from every other sample, except for F1 and F4. Because of its extremely high sucrose content, control has the highest TSS. Compared to CPS-meringue, NPS-meringue produced greater TSS. Moreover, while the ratio of coconut palm sugar is increasing higher than white sugar, the brix value became smaller. Prijono and Rachmatika (2020) used a hand-held refractometer to measure the °Brix of a palm sugar solution and discovered that the CPS solution diet was lower (14.0° Brix) than the NPS solution (15.0°Brix). This discrepancy may exist because NPS contains slightly more minerals than CPS which was proven by Prijono and Rachmatika (2020) who learned the ash content (mineral) of nypa palm sugar was 3.76% and coconut palm sugar was slightly lower at 3.59%. Higher mineral content can enhance solution density and increase light reflection when it passes through a watery medium, leading to a higher °Brix (Pontoh, 2013).

3.1.2 pH

The pH of the formulations is then ordered descendingly starting with control and moving up to F1, F2, F3, and F4 (Table 3). The current finding was consistent with a report by Muhammad *et al*. (2021) that CPS sap has a higher pH value of 5.52. Next, Saengkrajang *et al*. (2021) discovered that the pH of NPS sap ranged from 5.1 to 5.4, which was also regarded as mildly acidic. The NPS sap had a lower pH value than the CPS sap, according to this study. Kurniawan *et al*. (2018) also noted in their study that the acid created by microbial activity will lead the palm neera to have a pH below 7. Hence, the pH would be close to 5. In contrast, multiple investigations have found that white sugar has a pH of roughly 7, which was thought to be neutral (Singh *et al*., 2013). Kim *et al*. (2016), have signified that the typical pH of meringue is only 7.0. However, the meringue pH in this study ranges from 8.3-9.5 even after the addition of low-pH palm sugars. The high results from this study may be attributable to something like the aged egg white's elevated pH, from 7.6 for a fresh one (Eke *et al*., 2013) to 9.3-9.5 in a few days of storage (Peric *et al*., 2017). This explains the cause of the high pH value of meringue in this study.

3.1.3 Moisture

The purpose of measuring the moisture in whipped meringue is to determine whether there is a relationship between moisture and the functional characteristics of meringue incorporating palm sugar. According to Table 3, F4 was the sample with the highest moisture content and the only one that significantly differed from the other samples. F3 was not too far behind. The least amount of moisture was found in the control meringue. The moisture value increased as the amount of both palm sugars in the meringue increased, according to the results. NPS addition also produced meringue with a considerably higher moisture content than CPS addition. According to Arifin *et al*. (2020), the results showed that the moisture content of palm sugars was higher than that of sucrose. Besides that, Tai *et al*. (2021) who applied NPS powder to carrot cake implied that the moisture content of the carrot cake samples increased as the amount of NPS substitution increased. Similar results were also obtained by Nurhayati *et al*. (2022) who

https://doi.org/10.26656/fr.2017.9(1).189

applied CPS in dark chocolate, in which chocolate sweetened with CPS contained higher moisture than WS-containing chocolate.

3.1.4 Viscosity

According to the data, the F2 meringue with 70% CPS had the greatest viscosity measurement, followed by the F1 Control, the F3 and the F4 options. Only F4 significantly differed from the others ($P<0.05$). According to the findings, control and NPS-containing meringue were less viscous than CPS-containing meringues. The relationship between viscosity and foaming characteristics, such as foaming capability and stability, has been demonstrated in numerous investigations. Majumdar *et al*. (2012), for instance, suggested that the viscosity rises as the number of bubbles (foam capacity) increases. Another study by Lee and Kam (2013) found that viscosity would be higher in foam with higher stability (stronger foam). By evaluating these, it may be concluded that the samples' viscosity and foaming stability are related. The lowest foaming stability meringue, F4 (Table 3), had a viscosity that was much lower than that of the other samples. Although F4 meringue had the largest capacity for foaming, the foam bubbles might not be strong. Moreover, many researchers (Skelte *et al*., 2004; Yanniotis *et al*., 2006; Benoit *et al*., 2011) have looked into various additional factors that could impact the viscosity of certain foods. According to their research, food with higher moisture contents flows more quickly than food with lesser moisture, which results in reduced viscosity, which explains why NPS-meringue had the lowest viscosity. The viscosity of food with a lower pH, such as CPS-meringue, would be higher than in the Control.

3.1.5 Hardness and specific volume

From Table 3, the meringue cookies requiring greater force (g) to be cut was F4, followed by F3 with respective values of 1.92 and 1.73 g with no significant difference ($P>0.05$). The others, in descending order, were F2, F1 and lastly Control with values of 1.34 g, 1.25 g and 1.23 g, respectively, with no significant difference also ($P>0.05$). In terms of specific volume (Table 3), there were significant differences between all samples except between F1 and F2. Both results supported that F4 would have the hardest texture whereas control meringue had the least hard texture. Several studies have found that there is a negative correlation between specific volume and hardness (Aydogdu *et al*., 2018; Pang *et al*., 2021). Also, the stability and foaming capability of the meringue itself has a significant impact on the hardness of meringue cookies. The least hard, highest specific volume meringue cookies were produced by meringue with the highest capacity and stability. The key determinant of the outcomes is the low stability of F3 and F4 meringue foams. Although having significant foaming capacities, F3 and F4's limited stability caused the cookies to

Table 3. Total soluble solid (°Brix) of meringue solution; pH, moisture (%), viscosity (cp), foam capacity (%), foam stability (%) and colour profiles of whipped meringue; specific volume (cm^3/g), hardness (force, g) and colour profiles of meringue cookies.

Analysis			Formulation				
			Control	F1	F2	F3	F4
Meringue solution	Total soluble solid (°Brix)		65.20±0.100^{a}	62.50±0.120^{c}	61.10±0.100^{d}	63.70±0.350^{b}	62.10±0.120^{c}
	pH		9.43±0.030^{a}	8.88±0.061^{b}	8.75±0.038^{c}	8.66±0.010^{c}	8.30±0.010^{d}
	Moisture (%)		34.4131±0.4845^{b}	34.7295±0.1516^{b}	34.8742±0.3890^{b}	35.2408±0.5344^{b}	37.0957±0.2991^{a}
	Viscosity (cp)		46600±0.500^{b}	46750±0.500^{b}	46900±0.764^{b}	46650±0.577^{b}	45650±0.252^{a}
	Foam capacity (%)		155.83±1.443^{d}	164.17±1.443^{c}	174.17±3.819^{ab}	167.50±2.500^{bc}	175.83±3.819^{a}
Whipped meringue	Foam stability (%)	60 mins	100.00±0.000^{a}	100.00±0.000^{a}	100.00±0.000^{a}	100.00±0.000^{a}	100.00±0.000^{a}
		120 mins	100.00±0.000^{a}	100.00±0.000^{a}	100.00±0.000^{a}	99.67±0.144^{ab}	99.33±0.289^{b}
		180 mins	99.50±0.000^{a}	99.50±0.000^{a}	99.50±0.000^{a}	97.83±0.289^{b}	97.50±0.000^{a}
	Colour profile	L*	86.26±0.006^{a}	78.65±0.044^{b}	69.65±0.090^{d}	75.35±0.046^{c}	65.74±0.118^{e}
		a*	-0.93±0.010^{e}	3.03±0.069^{d}	4.95±0.066^{b}	3.41±0.015^{c}	7.07±0.121^{a}
		b*	6.80±0.031^{e}	18.81±0.052^{d}	22.70±0.060^{c}	24.96±0.119^{b}	26.18±0.110^{a}
	Specific volume (cm^3/g)		7.90±0.075^{a}	7.42±0.064^{b}	7.24±0.105^{b}	6.79±0.104^{c}	6.31±0.123^{d}
	Hardness (force, g)		1.23±0.025^{b}	1.25±0.057^{b}	1.34±0.050^{b}	1.73±0.175^{a}	1.92±0.021^{a}
Meringue cookies	Colour profile	L*	80.77±0.020^{a}	77.09±0.017^{b}	70.71±0.000^{d}	73.24±0.010^{c}	65.63±0.010^{e}
		a*	4.02±0.050^{e}	4.30±0.058^{d}	5.41±0.046^{b}	4.88±0.020^{c}	8.98±0.040^{a}
		b*	22.22±0.020^{e}	23.87±0.026^{d}	25.84±0.026^{c}	28.47±0.010^{b}	29.76±0.010^{a}

Values are presented as mean±standard deviation (SD) of triplicates. Values with different superscripts within the same row are statistically significantly different ($P<0.05$). Control: 100%WS, F1: 50%CPS, F2: 70%CPS, F3: 50%NPS, F4: 70%NPS, WS: White sugar, CPS: Coconut palm sugar, NPS: Nypa palm sugar.

https://doi.org/10.26656/fr.2017.9(1).189

collapse during oven baking, producing harder meringue cookies. These findings revealed that meringue with a high foaming capacity and stability will produce the study's most favourable outcomes. A study on the correlation between specific volume and hardness of meringue can be suggested to support the results.

3.1.6 Pictorial reference and colour profiles

The pictorial references of the meringue and meringue cookies for control, F1, F2, F3 and F4 are shown in Figure 1. The substitution of palm sugar in the meringue greatly influenced the appearance of the meringues and baked meringues, particularly in colour. All meringue and baked meringue with either CPS or NPS substitution were light brown in colour compared to the control which was white.

Based on the colour profiles measured by the instrument (Table 3), the control meringue sample lightness- L* parameter was significantly higher compared to other groups, indicating that the control had the lightest colour. On the other hand, F4 was the darkest in colour as its L* parameter was the lowest. The usage of palm sugars that are naturally brown had indeed significantly affected the meringue surface lightness values. The increase in chroma: redness (a*) and lightness (L*) of meringue with a higher percentage of NPS could be due to the high intensity of the dark brown colour of NPS compared to CPS. Therefore, significant differences ($P<0.05$) in each colour spectrum i.e., L*, a* and b*, between all meringues were discovered.

Maillard reaction and caramelization that happened during both sugar production and baking play a significant role in the colour profiles, as it produces melanoidin- a brown-pigmented by-product (Damodaran *et al*., 2007; Tamanna and Mahmood, 2015; Arifin *et al*., 2020) reported that the Maillard reaction rate is influenced by the nature of the reducing sugar. Each sugar exhibited different reaction rates and compared to other monosaccharides or polysaccharides, simple sugar with high glucose levels showed a higher reaction rate. Prijono and Rachmatika (2020) observed a high level of reducing sugars; fructose and glucose, in CPS, followed by NPS and lastly WS. This is in accordance with the present study which found the amount of reduced sugar affected its interaction with the egg white such as better aeration and foaming properties of meringue hence, influencing the meringue's colour profile to be darker in colour.

3.2 Functional properties

3.2.1 Foam capacity and stability

Foam capacity or overrun is the volume of foam that can be produced. In ranking order (Table 3), the foam capacity of whipped meringue from highest to lowest was F4, F2, F3, F1 and Control. The considerably appropriate low pH and high moisture content (Table 3) of formulation utilizing 70% NPS in F4 were favourable conditions for a high foaming capacity. Contrarily, control utilizing 100% WS had the lowest foam volume due to its neutral pH and lower moisture content than palm sugar-containing meringues. Foam capacity and foam stability are not always correlated with one another (Ivanova *et al*., 2018). Foam stability is the ability of meringue to retain its water (Goldfarb, 2016). Formulation with the most liquid drainage, at room temperature, after a certain period is considered the least stable. By referring to Table 3, control, F1 and F2 generally have the same stability level ($P>0.05$) as the liquid drainage only happened in 180 mins after foaming was finished. The result however is the opposite of the formulations utilizing NPS at which F4 had the least stability despite having the highest foaming capacity (overrun). Faster than the others, F3 and F4 started to have liquid drainage after 120 mins of foaming was finished. The water drainage of meringue indicated weaker bonds, hence not stable (Goldfarb, 2016). The study is indeed similar to other several findings that found a foam having higher moisture content would have high volume (capacity) or overrun but would have low stability (Sagis *et al*., 2001; Lomakina and Mikova, 2006), by means of more liquid drainage.

Aside from pH and moisture, other factors that might be affecting the functional properties of the foam are the protein content and the ionic strength. Foam capacity and/or foam stability increased as the protein concentration increased. Previous studies have determined that the protein content of CPS sap and NPS sap were 1.61% and 1.70%, respectively (Prijono and Rachmatika, 2020). The additional protein content from palm sugars might be one of the reasons why the foam capacity of meringue containing CPS and NPS was higher than the Control. Both functional properties would also increase when ionic strength increased from 0 -0.2 M (Olayide, 2003). From previous studies, CPS and NPS both have several polar minerals, they are particularly high in potassium and sodium (Muhammad *et al*., 2019; Saengkrajang *et al*., 2021), which contributes to high ionic strength. This factor would affect the hydrophobic interface, causing it to decrease the surface activity with which the hydrophilic residues are associated, thus, the foam stability is reduced (Alleoni, 2006). Hence, their findings are in line with the study results. Furthermore, aside from NPS having high ionic strength and protein concentration, NPS-meringue had lower pH and higher total moisture than CPS and WS-meringue, which influenced the foam capacity and stability to be significantly higher ($P<0.05$) and lower

https://doi.org/10.26656/fr.2017.9(1).189

(P>0.05), respectively.

3.3 Sensory properties

Sensory results that are presented in Table 4 below showed that there were no significant differences between all samples in terms of smoothness, adhesiveness, and sweetness. For colour, there was no significant difference in all meringue cookie formulations except for control as it had a shade of much lighter brown or almost white compared to others. Next, the most preferred aroma was F3 with no significant difference between F4. To add, no significant difference was determined between control, F1 and F2 as well as between F4 and F2. Panellists preferred the meringue cookies' aroma made with NPS compared to CPS which might be due to the caramel-like aroma of NPS. Then, hardness- one of the two texture profiles evaluated was described as one sound event perceived as sharp, clean, fast, and high-pitched sound on the first bite of the meringue cookies. From the hardness results using the texture analyzer (Table 3), F4 was expected to have the hardest texture among the samples. The theory later was proved right when F4 scored to have the hardest texture (Table 4). This was followed by F3, F2, control and F1 in an orderly manner. Adhesiveness was another texture profile determined which is described as the strength required to remove the sample completely from the palate using the tongue. Notably, all samples had no significant difference in adhesiveness. Lastly, the sensory analysis indicated there was no significant difference determined between control, F1 and F2 as well as between F1, F3 and F4. Meringue cookies using 50% NPS were the most accepted by sensory panelists with no significant difference between those that used 70% NPS.

4. Conclusion

In general, it can be concluded that CPS-meringue yielded better physiochemical, functional, and rheological properties than both WS- and NPS-meringue mainly due to moisture content, protein concentrations and ionic strength. NPS-meringue on the other hand had better sensorial properties as they had higher acceptability than WS- and CPS-meringue. It is suggested that for optimum overall acceptability of meringue cookies, the maximum concentration of NPS to be used in meringue should only be below 70%. In contrast, CPS has the potential to be incorporated more than 70%. Several recommendations can be suggested. The first one is the additional research on the cooking yield. Next is the study on lowering the total sugar content of meringue with palm sugar substitution as well as substituting palm sugars completely in meringue. Then, further analysis of the nutritional composition, total calorie content, glycemic index and antioxidant activity of both palm sugars and meringue products would also be beneficial to prove that palm sugar is the healthier alternative to white sugar.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Acknowledgements

The authors would like to acknowledge the Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam for the use of laboratory facilities.

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Table 4. Sensory analysis of meringue cookies.

Attributes/Variables	Formulation				
	Control	F1	F2	F3	F4
Colour	5.17±1.984^{b}	7.07±1.230^{a}	6.87±1.502^{a}	7.27±1.337^{a}	7.10±1.494^{a}
Smoothness	6.33±1.971^{ns}	7.33±1.348^{ns}	6.87±1.756^{ns}	7.17±1.234^{ns}	6.73±1.837^{ns}
Aroma	5.83±1.802^{c}	6.10±1.447^{c}	6.33±1.348^{cb}	7.33±0.994^{a}	7.27±0.907^{ab}
Hardness	7.00±1.017^{ab}	6.73±1.413^{b}	7.03±1.245^{ab}	7.20±1.375^{ab}	7.67±1.241^{a}
Adhesiveness	6.17±1.663^{ns}	6.40±1.380^{ns}	6.43±1.794^{ns}	6.93±1.112^{ns}	7.00±1.597^{ns}
Sweetness	6.93±1.617^{ns}	6.90±1.296^{ns}	6.67±1.826^{ns}	6.63±1.564^{ns}	6.60±1.850^{ns}
Overall acceptability	6.67±1.348^{b}	7.10±1.322^{ab}	6.43±1.251^{b}	7.63±0.928^{a}	7.60±1.192^{a}

Values are presented as mean±standard deviation (SD) of triplicates. Values with different superscripts within the same row are statistically significantly different (P<0.05). Control: 100%WS, F1: 50%CPS, F2: 70%CPS, F3: 50%NPS, F4: 70%NPS, WS: White sugar, CPS: Coconut palm sugar, NPS: Nypa palm sugar.

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