Research Article

Quality Characteristics of Cookies Incorporated with Pili (*Canarium ovatum*) Nut Flour

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ABSTRACT

Pili nuts are edible nuts that can potentially be used in many food products, including bakery products such as cookies. This research aimed to determine the nutritional composition and physical properties of cookies incorporated with pili nut flour at different formulations (F0: 0%, F1: 10%, F2: 20% and F3: 30%). Sensory evaluation for consumer acceptance with 50 untrained panellists was carried out on the different cookie formulations. The cookies were made with the addition of different ratios of pili nut flour to wheat flour. The incorporation of pili nut flour in cookies resulted in a significant increase ($p<0.05$) in ash, fat, crude fibre, protein and energy content. In terms of cookie texture, hardness values increased with an increase in pili nut flour content in the formulation. The spread ratio of the cookies also increased while the bulk density and water activity of the cookies decreased with an increase in the amount of pili nut flour in the cookie formulations. The results showed that incorporating pili nut flour in the formulation of cookies at a ratio of 30% (F3) was most preferred by consumers in terms of colour, aroma, texture, taste and appearance. In conclusion, this study found that the nutritional value of cookies could be improved by boosting the protein content, which is a common deficiency observed in cookies made with conventional wheat flour.

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1. Introduction

Pili trees can be found in Northern Australia, the Pacific Islands and Southeast Asia. Pili nuts are a type of nut, just like other nuts and legumes, that have many nutrients that are often taken for granted, which are also known as Pacific almonds. It is also a local product in Sabah and Sarawak that is easily available but underutilised by local people. Pili nuts are cotyledons found in pili fruit (Coro, 2020). They are teardrop-shaped and protected by a hard shell and outer coating that adheres to the shell (Coro, 2020). In the Philippines, pili nuts are commercially processed to produce pili nut oil, which is utilised domestically and exported for various applications. In addition to its high fat content, pili nut also has high content of vitamin E, calcium, zinc, potassium, thiamine, phosphorus, manganese and magnesium when compared to other nuts (Coronel, 1996). It also contains all the amino acids needed to be a complete protein source (Coro, 2020).

Pili nuts are rich in fibre, and consuming them provides a long-lasting feeling of fullness. The whole pili fruit contains 35.6-51.4% moisture, 11.5-15.7% protein, 69.2-76.6% fats and 2.59-4.32% carbohydrates. Pili nuts alone consist of as much as 71.1% fat, 11.4% protein and 8.4% carbohydrates (Coro, 2020). It has a rich buttery flavour and texture, perfect for use as a non-dairy substitute for nut milk and yoghurt (Coro, 2020). Sangalang *et al*. (2023) produced a calcium rich drink made from a mixture of adlai (*Coixlacryma-jobi* L.) and pili. The addition of pili nut in this product also increased the amount of protein and fat. Despite its traditional use in home-prepared foods in the Philippines, there is limited scientific research on the application of pili nuts in formulated food products.

To date, there is no report related to the use of pili nut flour for food products. Therefore, this study aims to produce cookies made from wheat flour incorporated with pili nut flour. The nutritional value and physical properties of cookies were evaluated for their quality characteristics.

2. Materials and Methods

2.1 Materials

Wheat flour, butter, sugar, vanilla essence and baking powder were purchased from ABC Supermarket, One Borneo Mall, Kota Kinabalu Sabah. The mature pili fruits were gifted by the Department of Agriculture Sabah, Tenom, Sabah.

2.2 Preparation of pili nut flour

Mature pili fruits were cleaned under running tap water and dipped in hot water for about 5 - 10 min before removing pili pulp following the method reported by Adin *et al.* (2025) with slight modifications. The shell was cleaned under running tap water before it was crushed using a pestle of a mortar. The nut was dried in an oven (TD-78T-SD, Thermoline, Australia) at 60 °C for 24 h (Hemphill & Martin, 1992). The dried nuts were ground using a Waring blender (Model HGBTWTS3, Dynamic Corporation of America, New Hartford, USA) and the oil was extracted using a mechanical pressing machine. The residue from the oil extraction process was used as a flour. Then, the flour was ground and sifted using a sieve shaker (Endecotts Ltd., United Kingdom) to achieve a particle size below 250 µm. The pili nut flour was stored in an airtight container at room temperature (25°C) until further use.

2.3 Production of pili nut cookies

Pili nut cookies were produced according to the methods of AACC (AACC, 2000) with slight modifications. Sugar and butter were mixed together in a mixing bowl. Other dry ingredients (wheat flour, pili nut flour, baking powder and salt) were weighed in another container according to the cookie formulations. Then, these ingredients were mixed into the wet mixture (sugar and butter) in the mixing bowl until a dough was

formed. The dough was flattened to a thickness of 5 mm and shaped using a round shape mold with a diameter of 6 cm. The cookies were placed on a baking tray and baked in the oven at 180°C for 10 min until the cookies turned brown. The cookies were then cooled on a wire rack at room temperature (25°C) for 30 min and stored in an airtight container until further analysis.

2.4 Determination of moisture, fat, ash, crude fibre, protein and carbohydrate contents

The moisture, fat, ash, crude fibre, protein and carbohydrate content of cookies were determined according to the method of AOAC (AOAC, 2000).

2.5 Determination of the energy content of cookies

The energy content of cookies was calculated using Atwater factors, where carbohydrates and proteins contribute 4 kcal/g and fats contribute 9 kcal/g (FDA, 2022).

2.6 Determination of the colour of cookies

The colour of cookies was determined using a Hunter Lab colorimeter. Before the colour was measured, the calibration process was carried out using black and white tiles. The colour values of the samples were measured in terms of L* (brightness), a* (redness or greenness) and b* (yellowish or bluish).

2.7 Determination of the spread ratio of cookies

The cookie diameter was measured by laying five cookies edge to edge and then taking the mean value (cm). Thickness was measured by stacking five cookies on top of one another and taking the mean value of thickness (cm). The spread ratio was calculated by dividing the average diameter by the average thickness of the cookies.

2.8 Determination of the bulk density of cookies

The bulk density of the cookies was determined according to the method of Okaka and Potter (1977) with slight modification. Fifty grams (50 g) of ground cookie samples were put into a 100 mL graduated cylinder. The cylinder was tapped several times to obtain a constant volume. The bulk density was calculated as weight per unit volume of samples.

2.9 Determination of the water activity of cookies

The water activity of cookies was carried out using a hygrometer machine (Hygrolab, Ro-tonic). The samples were ground into powder using a grinder and spread evenly in the container. It was then put into a hygrometer, and the water activity reading was recorded.

3.0 Determination of the texture of cookies

The texture of cookies was determined with Stable Micro Systems TA-XT Plus Texture Analyzer (Stable Micro System Ltd, UK) (Neilsen, 2017) according to the method of Manaf *et al*. (2019). A probe was used to penetrate the cookies to determine the hardness. It was used with a distance of 20 mm, pre-test speed 3 mm/s and post-test speed was 10 mm/s.

3.1 Sensory evaluation test

The sensory evaluation of cookies was conducted using a hedonic test. A total of fifty untrained panellists evaluated the appearance, colour, aroma, taste, crispiness and overall acceptability of the cookies made

from different formulations. Plain distilled water was also served to the panellists for rinsing the mouth before and after evaluating the cookie sample.

3.2 Statistical analysis

The data obtained were analysed by using Analysis of Variance (ANOVA) IBM SPSS Statistic Version 29 Software. One-way ANOVA test at a significance level of 95% was used to determine significant difference between the means of variables. All analyses were performed in triplicate and the results were recorded as mean ± standard deviation.

3. Results and Discussion

3.1 Nutritional composition

Moisture, ash, fat, protein, crude fibre, carbohydrate and energy of the cookies made from pili nut flour and control cookies are shown in Table 1. The moisture content of the cookies decreased [6.01% (F0) to 5.12% (F3)] as the percentage of the pili nut flour increased. Mamat and Hill (2018) stated that wheat flour contains approximately 12% to 15% moisture depending on the brand of flour. Pili nuts normally have a moisture content of 7.60% to 16% (Coronel, 1996). The decreasing percentage of moisture in cookies may be due to the use of dried pili nut flour. The cookies showed an increasing percentage of ash, fat, protein, crude fibre and energy with the increase of pili nut flour in the formulation. F3 had the highest percentage of ash (2.33%), fat (2.95%), protein (10.69%), crude fibre (1.29%) and energy (380.92 kcal) but lowest carbohydrate content of 77.62% among all cookie formulations. The ash content depends on the quality of flour used, which is affected by the mineral content in the flour (Pragati *et al.,* 2014). According to Millena and Sagum (2018), the ash content in pili nut was between 2.93% to 3.37% which was assumed to contain a higher amount of minerals when compared to the ash content in almonds, pistachios and peanuts which only have ash content between 1.90% to 2.40% (Moodley *et al.,* 2007). In this study, the inclusion of pili nut flour contributed to the higher ash content as it increased along with the increase in the content of pili nut flour. The control formulation, F0 (without pili nut flour), had the lowest ash content (1.28%) compared to other formulations. In general, wheat flour was reported to contain approximately 0.5% to 2% ash content (Bodor *et al*., 2024; Nasir *et al*., 2020).

Table 1. Nutritional composition of cookies made from different formulations of pili nut flour

Analysis	F0 (100WF:0PNF)	F1 (90WF:10PNF)	F2 (80WF:20PNF)	F3 (70WF:30PNF)
Moisture (%)	6.01± 0.30^{b}	5.53 ± 0.10^{ab}	5.32 ± 0.15^{a}	5.12 ± 0.20^{a}
Ash (%)	1.28 ± 0.49^{a}	1.56 ± 0.38^{ab}	1.98 ± 0.44^{ab}	2.33 ± 0.13^{b}
Fat (%)	2.26 ± 0.07^{a}	2.54 ± 0.06^{b}	2.74 ± 0.15^{bc}	2.95 ± 0.08^{c}
Protein (%)	7.38 ± 0.68^{a}	8.30 ± 0.26^{ab}	9.33 ± 0.39^{b}	10.69 ± 0.61^{c}
Crude fibre (%)	0.84 ± 0.20^{a}	1.11 ± 0.10^{ab}	1.25 ± 0.03^{b}	1.29 ± 0.05^{b}
Carbohydrate (%)	82.24 ± 0.75^{c}	80.97 ± 0.58^{c}	79.32 ± 0.18^{b}	77.62 ± 0.65^{a}

Energy (kcal)	377.82 ± 1.08[a]	378.75 ± 0.47[ab]	380.01 ± 0.91[bc]	380.92 ± 0.66[c]

Means with different letters in each row are significantly different ($p < 0.05$)
Abbreviations: WF: Wheat flour: PNF: Pili nut flour.

F3 cookie formulation with the highest ratio of pili nut flour (30%) showed the highest percentage of fat (2.95%), which is probably due to the remaining fat content in pili nut after extraction of its oil. According to Coronel (1996), pili nut had the highest fat content compared to other nuts. The control cookies (F0) which contained 100% of wheat flour showed the lowest (2.26%) fat content. Wheat flour has a low percentage of fat, around 1.81%, and almost 80% of the fat in cookies is dominated by additional fatty ingredients such as butter, shortening or margarine (Waters *et al.,* 2012). Fat is one of the basic components in bakery products, and it is important for texture and taste (Jacob & Leelavathi, 2007).

Based on Table 1, the protein content showed an increase in parallel with the increase in the amount of pili nut flour in cookies. Control cookies (F0) showed the lowest (7.38%) protein content while other formulations showed an increase in protein content (ranging from 8.30-10.69%). This difference may be due to the high protein content in pili nut flour. A study by Millena and Sagum (2018) found that pili nut had 9.97% of crude fibre content which may result in a high percentage of crude fibre in cookies incorporated with pili nut in the current study (Table 1). On the other hand, carbohydrate content was the highest in F0 cookies, showing that the addition of pili nut flour did not increase the carbohydrate content in other formulations (F1, F2 and F3). According to Coro (2020), pili nuts contain the lowest carbohydrates compared to other nuts. The energy content was slightly increased in cookies made from incorporated pili nut flour. The highest energy content was found in the F3 formulation, which could be mostly influenced by the high protein content of 10.69% (Table 1). As stated by Coro (2020), pili nuts are basically a complete source of protein as the formulation contains the lowest amount of carbohydrate.

3.2 Physical analysis

The cookies of F0 showed slightly brighter colour compared to other cookie formulations added with pili nut flour as shown in Figure 1. There was a significant difference ($p<0.05$) between all cookie formulations in terms of L* value. This may be due to the colour of the pili nut flour, which was slightly darker compared to wheat flour. All cookie formulations showed positive a* (ranging from 2.46 to 2.67) and b* values (ranging from 24.58 to 26.79), which indicated that the cookies had colour tones leaning towards red (due to positive a*) and yellow (due to positive b*). Therefore, the cookies appeared to have a reddish-yellow or golden-brown colour, which is typical and desirable for baked products like cookies.

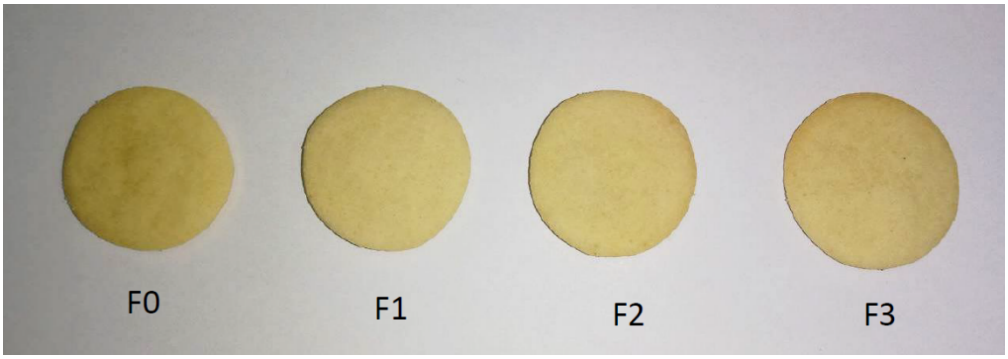

Figure 1. Cookies made of wheat flour (F0) and addition of pili nut flour at different ratios (F1, F2 and F3)

Table 2. Physical properties of cookies made from different formulations of pili nut flour

Analysis		F0 (100WF:0PNF)	F1 (90WF:10PNF)	F2 (80WF:20PNF)	F3 (70WF:30PNF)
Colour	L*	81.61 ± 0.52^{b}	80.01±2.17^{ab}	79.53± 0.26^{ab}	78.42 ± 0.13^{a}
	a*	2.46 ± 0.41^{a}	2.46 ± 0.41^{a}	2.50 ± 0.29^{a}	2.67 ± 0.16^{a}
	b*	25.58 ± 0.70^{a}	24.58 ± 2.81^{a}	26.57 ± 0.86^{a}	26.79 ± 0.29^{a}
Spread ratio		5.31 ± 0.33^{a}	6.07 ± 0.31^{ab}	7.10 ± 0.54^{bc}	7.45 ± 0.48^{c}
Bulk density (g/mL)		0.62 ± 0.06^{a}	0.52 ± 0.03^{a}	0.56 ± 0.06^{a}	0.49 ± 0.06^{a}
Water activity (aw)		0.57 ± 0.03^{a}	0.55 ± 0.05^{a}	0.56 ± 0.02^{a}	0.56 ± 0.02^{a}
Hardness (N)		981.78± 0.07^{a}	1186.08± 0.10^{b}	1371.73± 0.12^{c}	1464.67± 0.06^{d}

Means with different letters in each row are significantly different ($p < 0.05$)
Abbreviations: WF: Wheat flour: PNF: Pili nut flour.

The spread ratio of cookies increased with the increase in the amount of pili nut flour in the cookies. Cookie F0 formulation had the lowest (5.31) while F3 had the highest (7.45) width ratio (Table 2). These results showed that F3 had the largest diameter with the thinnest produced cookies. Higher spread ratio correlates with coarse-grained flours, which have lower water-holding capacities that affects dough viscosity (Mancebo *et al.*, 2015). There was no significant difference ($p>0.05$) on the bulk density of all cookie formulations. According to Dogan (2006), bulk density is an index that determines the sensory texture of cookies. The lower the cookie density, the crunchier the cookie. Bulk density is also influenced by particle size and flour density which are crucial for packaging and storage. The water activity in cookies showed no significant difference ($p>0.05$) among all cookie formulations. The rate of water activity is closely related to the rate of moisture content in a product (Mannhein *et al.*, 1994). The rate of water activity plays a role, where lower water activity refers to low moisture content, which helps in a longer shelf life. The hardness of the cookies ranged from 981.78 to 1464.67 N with F3 being the hardest among all of the formulations tested. Cheng and Bhat (2016) stated that the harder texture in cookies are attributed to the increase in protein content and interaction during dough development and baking.

3.5 Sensory evaluation

The sensory characteristics of both control and pili nut flour cookie formulations are shown in Table 3. According to Everitt (2009), cookies with a score of 5 or higher were considered acceptable (Yildiz & Gocmen, 2020) while cookies with scores of 7 or above indicated high sensory quality. The results showed that all of the cookies had similar appearance and colour that were not significantly different ($p>0.05$). According to Table 3, the aroma, crispiness, taste and acceptability increased with the increase in pili nut flour in the cookie formulation. According to Gonzales and Nunez (2020), who conducted a study on pasta made from pili nut flour, panellists were found to really like the pasta because of the aroma from pili nut itself. The sensory evaluation data showed that the panellists preferred the F3 cookie formulation which contained the highest amount of pili nut flour (30%). Cookies with 30% of pili nut had a more nutty aroma and this improved overall sensory qualities. The increase in fat content in the F3 formulation may also have contributed to its enhanced aroma and mouthfeel, which in turn could explain the higher scores for taste and overall acceptability.

Table 3. Sensory characteristics of cookies made from different formulations of pili nut flour

Attribute	F0 (100WF:0PNF)	F1 (90WF:10PNF)	F2 (80WF:20PNF)	F3 (70WF:30PNF)
Appearance	7.50 ± 1.39^{a}	7.46 ± 1.50^{a}	7.46 ± 1.43^{a}	7.56 ± 1.47^{a}
Colour	7.10 ± 1.52^{a}	7.08 ± 1.67^{a}	7.12 ± 1.60^{a}	7.32 ± 1.50^{a}
Aroma	7.22 ± 1.58^{a}	7.40 ± 1.39^{a}	7.44 ± 1.39^{ab}	8.14 ± 1.11^{b}
Crispiness	6.78 ± 1.78^{a}	7.20 ± 1.64^{ab}	7.56 ± 1.26^{bc}	8.04 ± 1.14^{c}
Taste	6.78 ± 1.94^{a}	7.14 ± 1.40^{ab}	7.28 ± 1.44^{ab}	7.88 ± 1.41^{b}
Overall acceptance	7.02 ± 1.74^{a}	7.22 ± 1.39^{a}	7.40± 1.20^{a}	8.02 ± 1.24^{b}

Means with different letters in each row are significantly different ($p < 0.05$)
Abbreviations: WF: Wheat flour: PNF: Pili nut flour.

4. Conclusion

The F3 cookie formulation (30% of pili nut flour) was rated the most acceptable by the panellists as it showed that all attributes tested in sensory evaluation obtained the highest score compared to other cookie formulations. The nutritional composition of the F3 cookie formulation also consisted of a higher percentage of ash, fat, protein, crude fibre and energy contents as compared to other cookie formulations. The exceptionally high protein content in the F3 cookies shows that these cookies could be an alternative new source of protein for human consumption. Further investigation on the functional and antioxidant properties of the cookies could be done in the future.

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