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Textural and sensorial properties of cookies prepared by partial substitution of wheat flour with unripe banana (*Musa* x *paradisiaca var. Tanduk* and *Musa acuminata var. Emas*) flour

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Abstract

The textural and sensorial properties of the cookies prepared by partial substitution of wheat flour with two types of unripe banana flour (UBF) were studied. The green matured unripe banana (*Musa x paradisiaca var. Tanduk* and *Musa acuminata var. Emas*) was used to partially substitute the usage of wheat flour at 0% (control), 25% and 50% level in the formulated plain cookies. Textural (hardness) and sensorial properties were conducted on all samples. Substitution of UBF to formulation of cookies had increased the hardness of cookies (ranging from 967 N to 1665 N) compared to the control except for substitution of Emas banana flour (EBF) at 50% which was not significantly difference ($p > 0.05$) with control sample. The substitution of 25% of Tanduk banana flour (TBF) showed the highest mean score in overall acceptability (6.81 ± 1.18) compared to all treated samples. TBF substitution is feasible up to 50% substitution while for EBF, the substitution only up to 25% level in this study.

Introduction

Cookies can be classified as ready to eat and convenient foods. Traditionally, the process of cookies making are fairly simple with basic ingredients consist of flour, eggs and sugar. Generally, cookies are recognized as flat, hard and crunchy food. Normally, cookies are classified according to their method of preparation such as drop, moulded, presses, refrigerated, bar or rolled. Apart from that, the dominant ingredients that been used in the formulation also commonly being used to classify the cookies, for example, nut cookies, fruit cookies and chocolate cookies.

Bananas are produced in enormous quantities in tropical and subtropical areas (Zhang *et al*., 2005). Nowadays, the harvesting of *Musa* plant had become a huge contribution to human society since it produces the fourth most important food in the world today (after rice, wheat, and maize) (Nelson *et al*., 2006). Besides that, the crop is labelled as one of major importance to the people in the growing areas as it forms a major portion of the annual income and a source of food (Zhang *et al*., 2005). In Malaysia, banana is the second largest cultivated fruit crops after durian, covering about 26,000 hectares with a total production of 530 000 metric tonnes (Chai *et al*., 2004).

There are tremendous interest in fruits that can be considered as functional ingredients to be incorporated in product's formulation in order to enhance the product's final quality such as crispiness, expansion and crunchiness. At the same time, the efforts to produce healthy food product that can provide health beneficial to consumer still a challenge among the manufacturers. This phenomenon rise in conjunction with increasing diseases raised from the improper diet that lack of indigestible fractions such as resistant starch and fibre.

Banana is one of the fruits that can be considered which can improve the health of consumers (dietary fibre (~14.5%), resistant starch (17.5%)) (Juarez-Garcia *et al*., 2006). However, the main component of banana (starch) drops from 70 to 80% in the pre-climacteric (ripening process prior to starch breakdown) period to less than 1% at the end of the climacteric period (Zhang *et al*., 2005). Thus, the production of banana flour with maximum starch content can be obtained by processing the unripe banana (matured, green banana) compared to ripe banana.

Fibre and resistant starch helps in preventing colon cancer because they are substrate for the colonic microorganisms, which then forming metabolites including short-chain fatty acids (SCFA), mainly acetic, propionic and butyric acid (Elmstahl, 2002). These short chain fatty acids make the environment of the colon more acidic by lowering the intestinal pH (Murphy *et al*., 2008), thus less desirable for bacteria's growth. Resistant starch consumption has also been related to reduce postprandial glycemic and insulinemic responses, which may have beneficial

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implications in the management of diabetes (Tharanathan and Mahadevamma, 2003).

There are previous studies that had been done to enhance the nutritional quality of cookies by utilizing different composite flour from various types of food sources in cookies (Singh *et al.*, 2003; Chinma and Gernah, 2007; Singh *et al*., 2008; Noor Aziah and Komathi, 2009; Ubbor and Akubondu, 2009). The purpose of this study was to evaluate the effects of substituting various amounts of wheat flour with UBF into cookies on textural and sensory attributes.

Materials and methods

Materials

Mature green index 2 banana, (*Musa x paradisiaca var. Tanduk* and *Musa acuminata var. Emas*) was obtained from a local farm in Selangor, Malaysia and processed into flour according to a modified method described by Saifullah *et al.* (2009). The banana flour was prepared from two types of banana, which are *Tanduk* banana (cooking type) and *Emas* banana (dessert type). The other ingredients that were used in production of cookies were sugar, butter, and wheat flour obtained from Giant Hypermarket, Seksyen 13, Shah Alam, Selangor, Malaysia. All the chemicals used were of analytical grade and purchased from Merck Co. (Darmstadt, Germany).

Sample preparation

The method for UBF production was adapted from study done by Saifullah *et al.* (2009) with slight changes made. The bananas were washed with the potable water to remove any dirt on the fruits to avoid physical contamination. The bananas then were peeled manually and sliced longitudinally to about 5 mm thick and dipped into 0.5% citric acid solution for 10 minutes. After that, the sliced pulps were dried at 60°C for 24 hours in a cabinet dryer (Vision Scientific, Malaysia). After drying, the dried pulps were milled using rotary type hammer mill (CNS, Taiwan) and sieved to pass through 60 mesh screens. The flours were stored in a plastic container in cold and dry place before further analysed.

Evaluation of banana flour

Physical analysis

The UBF were analysed in terms of percent yield and particle size. The percent yield of unripe cooking and dessert banana flour was calculated by dividing the weight of flour which resulted from the milling process with the initial weight of raw material (banana) that were used. Particle size of the resulted flour was determined by using sieving method describe by Nishita and Bean (1982) with slight modifications. Sieving was done by pouring 100 g flour on a sieve shaker (Retsch Sieveshaker, Germany). The flour were sieved through 2.0 mm, 1.0 mm, 0.85 mm, 0.60 mm, 0.425 mm and 0.15 mm sieves (2.0 mm sieve topmost and 0.15 mm sieve at the bottom) for 10 minutes. The percentage of flour remained in each sieve was calculated. The median particle size (PS 50) was determined as the sieve size (in mm) through which 50% of flour would pass.

Chemical analysis

Moisture and crude fibre was determined according to AOAC method. Total starch content of the UBF were analysed according to method of Goni *et al.* (1997). Briefly, 50 mg ground sample of flour was dispersed in 6 ml of 2M KOH and the mixture was incubated for 30 minutes at room temperature. The solubilised starch was then be hydrolysed by adding 60 µL of amyloglucosidase and incubating at 60°C for 45 minutes by shaking in water bath. After centrifugation (15 minutes, 4500 g), the supernatant was measured using glucose oxidase-peroxidase kit. The total starch content in the sample was calculated as mg of glucose x 0.9.

Analysis of composite flour

Composite flours refer to the combination of two or more different type of flours. The composite flours in this study consist of combination of UBF and wheat flour at different percent of substitution.

Resistant starch

Resistant starch (RS) contents of the composite flour were determined according to the method of Hung *et al*. (2013). Cookies (1 g) was mixed with 25 ml of acetate buffer (pH 6.0) and then boiled for 30 minutes in a water bath. The resulting suspension was treated with amylase (7000 U/g starch) at 37°C for about 2 hours and followed by amyloglucosidase (50 U/g starch) at 60°C for 30 minutes. The mixture was centrifuged (1500 x g, 15 min) and the resulting sediment was washed with distilled water for three times and then dried at 50°C for 48 hours. The percent of resistant starch was calculated as the weight of the remaining residue comparing to that of the initial sample. A blank without flour sample was used to minus the contamination of the enzymes.

Formulation of cookies

Composite flour with different proportion of wheat flour and UBF were prepared as shown in Table 1, with 100% wheat flour served as control. A digital weighing balance (Ohaus, USA) and a food mixer (Panasonic, Malaysia) were used for weighing and mixing the flours, respectively.

Preparation of cookies

Firstly, oven was preheated at 170°C. The butter was beaten in a food mixer and sugar was added. Then, sifted flour sample was added in the mixture. The mixture was then mixed and kneaded until it became dough. By using piping bag, the dough was moulded into walnut sized balls, placed on the greased tray and finally, baked in the oven for 15 minutes until a golden brown colour was obtained. They were allowed to cool before being packed in polyethylene bag and stored in cold and dry place until further analysis being done.

Evaluation of cookies

Textural properties (hardness)

The method for the Texture Analyzer (TA-XT2i Plus, Germany) was obtained from the manual supplied by the supplier. The cookie was supported at two points on a snack pot fixture. As the test started, the probe (3-point bending rig, 5 kg load cell) moved downward toward the sample, until the initial resistance of a given load detected at the sample surface. Then, the probe was rapidly compressed the sample over 5 mm distance. The test caused the cookie to break in half at the weakest point. The cookie hardness was determined by maximum force (N) during compression.

Sensorial properties

Coded samples of cookies were presented to 30 panelists. Each panelist received five cookies, one for each formulation (control, 25% TBF, 50% TBF, 25% EBF, 50% EBF), presented in individually booth. The cookies were coded with random three-digit numbers. A 9 point Hedonic scale rating was used to evaluate the sensory attributes of cookies (appearance, colour, taste, crispiness and overall acceptability), where 1 = dislike extremely and 9 = like extremely. The 100% wheat flour cookie was used as control.

Statistical analysis of data

All data obtained were expressed as mean ± standard deviation. Data was analysed by using one-way Analysis of Variance (ANOVA) using SAS 9.1. Duncan's Test was conducted to analyse differences between mean at 95% confidence interval.

Result and Discussion

According to the results obtained, it was found that the percent (%) yield of *Tanduk* banana flour (TBF) was higher than *Emas* banana flour (EBF) in which both of them recorded about 25.6% ± 2.05 and 19.3% ± 3.78, respectively (not shown in table). According to Widowati (2003), the percent yield of the banana depends on the maturity index as well as starch content of the fruit. Higher maturity index fruit have lower starch content, thus lead to lower yield of flour obtained. In this study, the starch content of TBF is higher compared to starch content of EBF (Table 2). This explained the higher percent yield obtained for TBF. Apart from that, the amount of water of the fruit before drying also affect the amount of flour produced after drying (Histifarina *et al*., 2012). The higher the amount of water in the pulp before drying, the lower the yield of flour obtained.

The particle size of the TBF and EBF is showed in Figure 1. From the result obtained, both TBF and EBF had the particle size smaller than 2 mm as there is no flour retention in the sieve. More than 50% of the flour (both TBF and EBF) passed through the sieve with size 0.15 mm (150 µm). Thus, the PS 50 of both flour are that of 0.15 mm. Apart from that, the non-uniform particle size can be observed by flour retention in the various size of wire mesh. The same pattern of result was also reported by Bazerra *et al.*

Table 1. Formulation for composite flour (%) for cookies production

Flour blends	Wheat flour	*Tanduk* banana flour (TBF)	Emas banana flour (EBF)
A (control)	100	-	-
B (25% TBF)	75	25	-
C (50% TBF)	50	50	-
D (25% EBF)	75	-	25
E (50% EBF)	50	-	50

Table 2. Chemical composition of banana flour (BF) prepared from unripe fruit

Flour sample	*Moisture (%)	*Crude fibre (%)	*Total starch (%)
TBF	12.43[a] ± 0.20	1.65[a] ± 0.06	58.81[a] ± 0.36
EBF	10.91[b] ± 0.05	1.06[b] ± 0.07	21.97[b] ± 0.51

Values followed by the different letter in the same column are significantly different ($p < 0.05$)
* Mean ± standard deviation (n = 3)

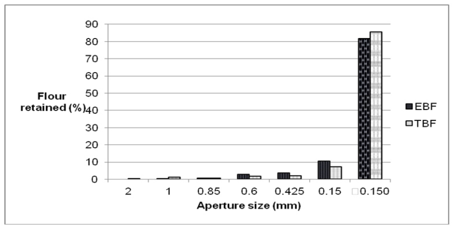

Figure 1. Particle size of banana flour (mm).
Tanduk banana flour (TBF), Emas banana flour (EBF)

Figure 2. Banana flour produced from two varieties of banana.
Tanduk banana flour (TBF), Emas banana flour (EBF).

Table 3. Resistant starch (RS) in composite flours consist of banana flour (BF) and wheat flour

Analysis	Tanduk25%	Tanduk50%	Emas25%	Emas50%
*Resistant starch (%)	$25.33^b \pm 0.14$	$28.57^a \pm 0.36$	$22.98^d \pm 0.27$	$24.66^c \pm 0.43$

Values followed by the different letter in the same column are significantly different ($p < 0.05$)
* Mean ± standard deviation (n = 3)

Table 4. Hardness for control and ultimate level of banana flour (BF) – incorporated cookies

Texture (N)	A	B	C	D	E
*Hardness	$976.70^d \pm 19.54$	$1498.29^b \pm 19.64$	$1665.72^a \pm 16.72$	$1390.27^c \pm 6.55$	$967.66^d \pm 8.64$

A (100% wheat flour); B (25% TBF); C (50% TBF); D (25% EBF); E (50% EBF).
Values followed by the different letter in the same column are significantly different ($p < 0.05$)
* Mean ± standard deviation (n = 5)

Figure 3. Sample for control and ultimate level of banana flour (BF) – incorporated cookies.
A (100% wheat flour); B (25% TBF); C (50% TBF); D (25% EBF); E (50% EBF).

(2013) who found that the particle size distribution of banana flour peeled and unpeeled to be non-uniformed as the result of raw material accumulation on the surface of the inert material (grain), generating particles with different sizes during drying.

The chemical analysis of the flour can be observed in Table 2. According to the results obtained, moisture content of TBF is higher than EBF. The amount of crude fibre also higher in the TBF compared to EBF. Water holding capacity of the flour could be related to the physical state of starch (Waliszewski *et al*., 2003), dietary fibre and protein in the flour (Alkarkhi *et al*., 2011). Rodriguez-Ambriz *et al.* (2008) reported that amylase in starch has the capacity to bind water molecules, thus gives higher water holding capacity. Apart from that, the high water holding capacity could be attributed to the fibre and protein (Alkarkhi *et al.*, 2011). This explained the results obtained where TBF has higher amount of starch and crude fibre, thus lead to the higher moisture content.

The moisture content for both flour are slightly higher than those reported by Abbas *et al*. (2009), who indicated that Cavendish and Dream banana flour contain moisture content of 9.57% and 8.17%, respectively. The crude fibre content of both type of flour were higher compared to the study done by Egbebi and Bademosi (2011), who found the amount of crude fibre in unripe banana flour was 0.7%.

From the study, it was found that the total starch content in unripe TBF (59%) is higher than EBF (22%). The amount of total starch in both types of UBF were lower compared to the total starch content that presented in study by Vatanasuchart *et al.* (2012) in flour produced from Thai bananas which varied from 71% to 91%. The flour made from cooking type banana (TBF) has higher amount of total starch compared to the dessert type banana (EBF). Even though the unripe cooking type banana is very similar to the unripe dessert type banana in outward appearance (Happi Emaga *et al*., 2007), but cooking type banana's flesh is starchier compared to dessert type banana (Mohapatra *et al*., 2010). This explained the difference in starch content between the two varieties.

Referring to the Table 3, composite flour with 50% level of substitution had higher amount of resistant starch (RS) compared to 25% level of banana flour substitution. From the results obtained, it can be interpreted that the degree of substitutions affects the amount of resistant starch present in the composite flour where the higher level of substitution resulted in higher amount of resistant starch.

The result obtained from this analysis was in accordance with the study that conducted by Bhatawale *et al.* (2012) in which the relationship between resistant starch and banana flour substitution was directly proportional. Raw starch granules have starch that is tightly packed in a radical pattern and also slightly dehydrated. This is known as resistant nature of type 2 RS that exist in food products such as raw potato, green banana, and high-amylose starch (Englyst *et al*., 1992). The structure of the starch limits the accessibility of enzymes (Sajilatha *et al*., 2006). This situation explained the amount of resistant starch that increase with the increase in BF substitution.

The hardness of the cookies (Table 4) varied from 967.7 N to 1665.7 N. TBF 50% recorded the highest hardness (1665.7 N) compared to the other samples. Substitution of different type of banana flour gives different effect to the hardness of the cookies. From the results obtained, the increase of cookies' hardness with increase substitution of TBF can be observed. In the formulation of the cookies, water plays a major role to determine the conformational state of biopolymers as well as affecting the nature of interactions between the various constituents of the formulation (Eliasson and Larsson, 1993). Thus, dough structuring of the cookies, can be said, affected by the amount of water used in the formulation of the cookies. Sai Manohar and Haridas Rao (1999) stated that if the proportion of water is too low, the dough becomes brittle and not consistent The low amount of water causes delays or prevents starch gelatinization or pasting during baking process of cookies (Baltsavias *et al*., 1999). Consequently, some of the starch granules remained in their native condition during baking process and did not form a continuous structure (Kulp *et al*., 1991). Apart from that, proteins do not aggregate and hydrate enough to form a gluten network (Chevallier *et al*., 2002). This lead to the increase in hardness of

Table 5. Measurement of sensory evaluation for control and ultimate level of banana flour (BF) – incorporated cookies.*

Sample	Sensory appearance	Colour	Taste	Crispiness	Overall
A	$7.34^{a} \pm 1.07$	$7.53^{a} \pm 1.14$	$6.78^{a} \pm 1.16$	$6.78^{a} \pm 1.21$	$7.22^{a} \pm 1.01$
B	$6.81^{ab} \pm 1.06$	$6.88^{ab} \pm 1.13$	$6.69^{a} \pm 1.18$	$6.09^{b} \pm 1.20$	$6.81^{ab} \pm 1.18$
C	$6.41^{b} \pm 1.48$	$6.75^{b} \pm 1.32$	$6.59^{a} \pm 1.32$	$5.50^{b} \pm 1.34$	$6.50^{bc} \pm 1.34$
D	$4.91^{c} \pm 1.61$	$4.84^{c} \pm 1.72$	$6.28^{a} \pm 1.40$	$5.69^{b} \pm 1.09$	$6.03^{c} \pm 1.28$
E	$4.25^{c} \pm 1.65$	$4.34^{c} \pm 1.66$	$5.22^{b} \pm 1.81$	$5.50^{b} \pm 1.37$	$4.91^{d} \pm 1.91$

A (100% wheat flour); B (25% TBF); C (50% TBF); D (25% EBF); E (50% EBF).
Values followed by the different letter in the same column are significantly different ($p < 0.05$)
* Mean ± standard deviation (n = 30)

the cookies obtained.

This trend can be observed in the formulation of cookies with TBF substitution where TBF-incorporated cookies shown increased in hardness compared to the control cookies. The same pattern was found by Ajilata *et al.* (2008) where the hardness of soft dough biscuits increase as substitution of mango peel flour is increased. On the other hand, different trend was observed in EBF-incorporated cookies where the cookies' hardness decrease with increase substitution of EBF. The hardness of EBF-incorporated cookies are higher at 25% level of substitution compared to 50% EBF substitution. Due to substitution of EBF, there is dilution to the amount of flour protein mainly gluten presents in the formulation. Gluten, which is a major protein component in wheat flour (Torbica *et al*., 2010) is responsible to gives textural characteristics in bakery industry. Even though the functionality of the gluten is not critical in cookies compared to bread or cake, gluten still function to stabilize the texture of the biscuit.

There is no significant difference in hardness that can be observed between 50% EBF-incorporated cookies with the control sample. The dilution of the gluten lead to weaker formation of network between the ingredients, thus lead to lower amount of hardness of EBF-incorporated cookies while in the control sample, the starch may be fully gelatinize that resulted in cookies with low hardness. Similar trend can be observed in the study done by Singh *et al.* (2008). The study indicated that the sweetpotato flour-incorporated biscuit has became soft with increased sweetpotato flour content. Another study conducted by Bhatawale *et al*. (2012) also found that, the hardness of rice papad dough decreased significantly with increasing banana flour concentration. Singh *et al.* (2003) stated that, the differences in swelling behaviour of the individual starch granules of different cultivars may have led to the formation of air zones of different volumes that resulted in cookies with different hardness.

There is a strong negative correlation between hardness of the cookies obtained by instrument measurement and crispiness of cookies obtained by sensorial analysis for TBF-incorporated cookies, $r^2 = -0.87771$, $p < 0.05$. This correlation indicates that the higher hardness of the cookies obtained by instrument measurement strongly lead to lower acceptability score in terms of crispiness given by the panelists. However, a low negative correlation between hardness of the cookies obtained by instrument measurement and crispiness of cookies obtained by sensorial analysis for EBF-incorporated cookies, $r^2 = -0.27478$, $p < 0.05$. This correlation indicates that higher hardness of the cookies obtained by instrument measurement slightly lead to lower acceptability score in terms of crispiness given by the panelists.

From the sensory evaluation result obtained (Table 5), TBF-incorporated cookies had higher mean score for all attributes both with 25% and 50% substitution compared to that of EBF-incorporated cookies. The control sample prepared from 100% wheat flour obtained highest mean score compared to the treated cookies samples in all attributes. It was observed that with the increased in BF substitution, there is decrease in appearance, colour, taste, crispiness and overall acceptability of the cookies. The low acceptability in colour for samples with substitution of the UBF may be due to banana flour that initially darker in colour compared to the wheat flour that lighter in colour. The colour of the cookies become darker as the baking process takes place. The substitution of 25% of TBF showed the highest score in overall acceptability (6.81 ± 1.18) compared to all UBF-incorporated cookies. Knuckles *et al.* (1997) reported that in sensory evaluation, products with score value of more than five for overall acceptability can be considered as a good quality product.

Cookies structures are primarily affected by three components which were sugar, flour, and eggs. According to Weaver (2006), flour affects the cookies structure in three ways. Starches is gelatinizing and will create the structure of the cookies when they are bake, gluten strands in the flour generate a chewy texture and high protein content aids to produce much chewier texture because with a higher protein content, hence more gluten strands are formed (Weaver, 2006).

Conclusion

The substitutions of the TBF lead to higher hardness of cookies with increase amount of substitution while the EBF substitutions lead to lower hardness of cookies with increase amount of substitution. In this study, substitution of UBF was carried out to 50% substitution, thus the acceptable of TBF-incorporated cookies are feasible up to 50% substitution while for EBF the substitution only up to 25% level. Even though the overall acceptability of treated cookies is inferior to the acceptability of the control, but these cookies has score more than five in overall acceptability, thus, they can be considered as a good quality products.

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