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Influence of Partial Substitution of Wheat Flour with Banana (*Musa paradisiaca var. Awak*) Flour on the Physico – Chemical and Sensory Characteristics of Doughnuts

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Abstract: Evaluation on the physicochemical and sensory properties of wheat flour doughnuts substituted with banana flour (BF) was investigated. Wheat flour was substituted with green banana (*Musa paradisiaca var. Awak*) flour at 0% (control), 10%, 20% and 30% levels in yeast-raised doughnut prepared by the straight dough method. Chemical (moisture, fat, protein, ash, carbohydrate, crude fibre, total dietary fibre and caloric content), physical (volume, specific volume and colour) and sensory evaluation were conducted on all samples. Chemical analyses result indicated a higher percentage of total dietary fibre and caloric content in doughnut substituted with BF than the control. Colour evaluation showed that the dough, crust and crumb of doughnut with BF ranged from 68.97 ± 0.59 – 84.78 ± 0.16 (red – yellow quadrant). The change from light to darker colour correlated with the amount of BF added. Results also showed that the volume and specific volume was significantly affected ($p < 0.05$) by levels of BF substituted. Doughnut substituted with 20% BF showed the highest score in overall acceptability (6.71 ± 1.40).

Keywords: Doughnut, green banana, banana flour, dietary fibre, caloric

INTRODUCTION

Doughnut is a fermented, fried snack which is one of the most popular fried products throughout the world (Hatae *et al.*, 2003; Rehman *et al.*, 2007). Doughnuts are made by deep-frying dough that is a mixture of flour, water, egg, oil, sugar and milk (Hatae *et al.*, 2003). Doughnut made from non-enriched wheat flour lacks other essential nutritional composition such as dietary fibre, vitamins and minerals that are lost during the process of wheat flour refinement.

Banana belongs to the family Musaceae, genus *Musa* and is a general term embracing a number of species or hybrids in this genus. Bananas are an important food crop in many countries and grown extensively in the tropical and subtropical regions. The worldwide production of bananas in 2001 was 66.5 million metric tonnes (FAO, 2002) and increased to 102 million MT of which 68% was banana and 32% plantain (FAO, 2003). Banana is consumed directly as raw, ripe fruit or processed into pulp-liquid fruit, canned slice, deep-fried chips, toffees, fruit bars, brandy and others (Kachru *et al.*, 1994).

Musa paradisiaca is a type of plantain, usually is cooked before eaten and *Musa paradisiaca var. Awak* or locally known as 'pisang awak' is widely grown throughout Malaysia. Plantain is rich in starch (14% - 23% on a fresh weight basis) and therefore is considered as a possible source of starch for the food industry. Matured green banana can also be processed into flour and used as a source of starch which can be added to food. The flour can then be incorporated as an ingredient for bakery products which enhances the product's nutritional value.

At present, there is an increasing interest in fruits rich in dietary fibre that is associated with health promoting abilities. According to Chen and Anderson (1986), consumption of dietary fibre can prevent chronic diseases such as cardiovascular diseases, diabetes and colon cancer. Bananas contain high amounts of essential minerals such as potassium, magnesium and various vitamins such as A, B_1, B_2 and C. Besides nutritional and health values, bananas have economic gains, as mass production of banana flour (BF) will increase the demand for green bananas. This will encourage

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farmers to keep on tending the banana crop, as value of the banana will increase along with its usefulness.

Despite being a good dietary source, processed green mature banana flour has not been utilized as a food source to its full potential as an ingredient in bakery product–doughnut. The purpose of this investigation was to evaluate the effects of substituting various amounts of wheat flour with BF into doughnut on chemical composition, physical and sensory attributes.

MATERIALS AND METHODS

Materials

Mature green banana (*Musa paradisiaca var. Awak*) was obtained from a local market in Penang and processed into flour according to a modified method reported by Collins and Temalilwa (1981). Bread flour, dry yeast, full cream milk, vegetable shortening, emulsifier (Glyceryl monostearate, GMS), baking powder and ascorbic acid were obtained from Sunshine Trading, Penang. Eggs, salt and sugar were purchased from a local mini market in Penang. All the chemicals used were of analytical grade and purchased from Sigma Chemical Company.

Preparation of Doughnut

Doughnuts were prepared by the straight-dough method according to modified formulation (Braden, 1976). Ingredients consisted of wheat flour: 100%, water: 36%, shortening: 18%, egg: 10%, sugar: 6%, milk powder: 6%, baking powder: 1.4%, dry yeast: 1.12%, salt: 1%, emulsifier: 0.2% and ascorbic acid: 0.01%. A portion of wheat flour was replaced with an equivalent portion of BF (10%, 20% and 30%) and water was adjusted to produce a desired dough consistency. All ingredients were electrically mixed (Kitchen Aid, model: K5SS, USA) for 1 minute at speed 2 with the exception of shortening which was added later and mixed for another 10 min at speed 6. Mixing was further continued for 5 minutes at speed 8. The mixed dough was rested for 10 minutes at ambient temperature. The dough was sheeted to 12 mm thickness and cut with a doughnut cutter having a diameter of 6 cm. The cut pieces were then placed on a greased tray, covered with a damp cloth and proof for 30 minutes. The doughnuts were then deep-fried in corn oil at 185 ± 5°C on each side for 1minute.

Evaluation of Doughnut

(i) Chemical Analysis

Proximate Analysis

Moisture, crude protein, ash, crude fat and crude fibre contents of noodles were determined according to the AACC (2000) method. Protein content (%N x 5.7) was determined by the Kjedahl method. Moisture was determined by oven drying for 4 hours at 100-105°C. Ash was measured by dry combustion [AACC, 2000 (Method 08-01)]. Free lipids were measured by petroleum ether extraction, followed by evaporation to constant weight [AACC, 2000 (Method 30-25)]. Crude fibre was determined according to the procedure of AACC, 2000 (Method 32-07). Available carbohydrate was calculated as 100% - (% moisture + % ash + % fat + % protein + % crude fibre). All samples were done in triplicate.

(ii) Caloric Values

Caloric values for all samples were determined by calculation. Percentages for protein, crude fat and carbohydrate were multiplied with their respective factors. Caloric value (kcal/100g) = (% protein x 4) + (% crude fat x 9) + (% carbohydrate x 4). All samples were done in triplicate.

(iii) Total Dietary Fibre

Dietary fibre content was determined by enzymatic-gravimetric method according AOAC, 1990 (Method 985.29). Samples of dried and fat-free were gelatinized with heat stable -amylase and then enzymatically digested with protease and amyloglucosidase to remove the protein and starch present in the samples.

(iv) Physical Measurement

The volume of doughnuts was determined using the volume replacement method (AACC, 1984) and they were weighed after cooling for 30 minutes at ambient temperature. Three samples were randomly selected from each doughnut for physical measurements. Crumb and crust colour of doughnuts were measured by using Minolta colorimeter (model CM – 3500d) for Lightness (L*) and Hue values.

(v) Sensory Evaluation

A 9 point Hedonic scale rating was used in evaluating the sensory attributes of doughnuts, where 1 = dislike extremely and 9 = like extremely. The attributes evaluated were colour, odor, elasticity, hardness, oily, flavour and overall acceptability. Twenty panelists comprising of (10 males and 10 females) students and staff of the

Table 1: Proximate composition of control and different levels of Banana Flour (BF) – incorporated doughnuts*

Composition (% db)	Control	10% BF	20% BF	30% BF
Moisture content	32.87 ± 0.10^{c}	30.04 ± 1.13^{bc}	28.33 ± 1.04^{b}	22.96 ± 0.92^{a}
Crude fat	24.30 ± 0.71^{a}	28.58 ± 0.11^{b}	27.65 ± 0.05^{b}	31.44 ± 0.78^{c}
Crude protein	12.19 ± 0.01^{a}	10.58 ± 0.56^{b}	9.14 ± 0.34^{c}	8.37 ± 0.62^{c}
Ash	2.12 ± 0.03^{a}	2.10 ± 0.04^{a}	2.03 ± 0.07^{a}	2.24 ± 0.08^{b}
Crude fibre	1.89 ± 0.13^{a}	2.53 ± 0.64^{b}	4.72 ± 0.12^{c}	5.46 ± 0.66^{d}
Carbohydrate	28.75 ± 1.01^{bc}	26.17 ± 2.11^{a}	28.13 ± 1.44^{bc}	29.53 ± 1.63^{c}

Values followed by the same letter in the same row are not significantly different ($p < 0.05$)
* Mean ± standard deviation (n = 3)

School of Industrial Technology Department participated in the evaluation.

(vi) Statistical Analysis of Data

Data were analyzed with SPSS version 11.0 (Illinois, U.S.A) using one-way Analyses of variance (ANOVA). Significant differences were tested using the Duncan Multiple Range test. Three replications were used for chemical and physical measurements and two replications for sensory evaluation.

RESULTS AND DISCUSSION

Proximate composition results for fried doughnuts are shown in Table 1. The results indicate a decrease in moisture content with increase in percentage of banana flour (BF).The moisture content in BF-incorporated doughnut was found to be significantly lower ($p < 0.05$) than the control. This may be due to the low water holding capacity for banana starch than wheat starch. This was also reported by Ibadan *et al.* (1992). The water content from the doughnut could have evaporated during the deep – fat frying process. Therefore with high percentage of BF there will be more water loss from the doughnut during deep frying. Similar results were reported for French fries by Krokida *et al.* (2000). There was an increase in the percentage of crude fat with increase in BF in the doughnuts. This could have contributed by the increase in fat with increased in level of BF due to the oil absorbed to replace the pores. Similar observation was reported by Mellema (2003) for fried food. The protein content of BF doughnuts was significantly lower ($p < 0.05$) than the control and an inverse relationship with the amount of BF added. This was due to the relatively low percentage of protein in BF as compared to wheat flour. The 30% BF doughnuts was significantly different in ash content compared with the other samples. The ash content depends on the quality available in the flour (Kim, 1996) and thus corresponds to the higher mineral content (especially potassium) in BF which contributed to the significantly higher ash content in BF (3.7%; Suntharalingam and Ravindran, 1993) than wheat flour (0.43%; Watt and Merrill, 1963). Percentage of crude fibre in BF doughnut was higher than the control and increased significantly as wheat flour was substituted from 10% to 30% BF into doughnut. The relatively high percentage of crude fibre content was contributed from the hemicelluloses in the flour produced from green banana (Kayisu *et al.*, 1981). However, the percentage of crude fibre was lower compared to that of total dietary fibre (Table 2). This could be attributed to the solubilisation of hemicelluloses in alkali during the gravimetric determination of crude fibre. The carbohydrate content in samples ranged from 26.17% to 29.53%.

The soluble (SDF), insoluble (IDF) and total dietary fibre (TDF) contents of BF-incorporated doughnuts are shown in Table 2. BF-incorporated doughnuts had signifi-cantly ($p < 0.05$) higher content of SDF, IDF and TDF than the control. Ultimate increase in SDF, IDF and TDF contents were also noted with increased levels of BF added. The higher content of IDF than SDF in BF-incorporated doughnuts was due to the fact that green banana are high in IDF such as cellulose (1.42 ± 0.02%), hemicelluloses (6.08%) and lignin (0.14 ± 0.02%) (Kayisu *et al.*, 1981).

Caloric values for BF-incorporated doughnuts were significantly ($p < 0.05$) higher than the control (Figure 1). Caloric content was closely related to the fat content of doughnuts due to fat absorption during frying. Therefore, higher fat content in doughnut indirectly increased the caloric value of the doughnut.

Volume of the control sample was higher and significantly different ($p < 0.05$) from doughnuts incorporated with BF. The volume decreased with increase in BF as shown in Figure 2. This decrease

Table 2: Soluble dietary fibre (SDF), insoluble dietary fibre (IDF) and total dietary fibre (TDF) contents of control and different levels of banana flour (BF) – incorporated*

Sample	SDF (% db)	IDF (% db)	TDF (% db)
Control	1.09 ± 0.04[a]	1.99 ± 0.08[a]	3.07 ± 0.11[a]
10% BF	2.08 ± 0.04[b]	3.44 ± 0.06[b]	5.51 ± 0.85[b]
20% BF	2.16 ± 0.04[b]	4.40 ± 0.06[c]	6.56 ± 0.92[c]
30% BF	2.17 ± 0.05[b]	4.72 ± 0.82[c]	6.89 ± 0.18[c]

Values followed by the same letter in the same column are not significantly different (p < 0.05)
* Mean ± standard deviation (n = 3)

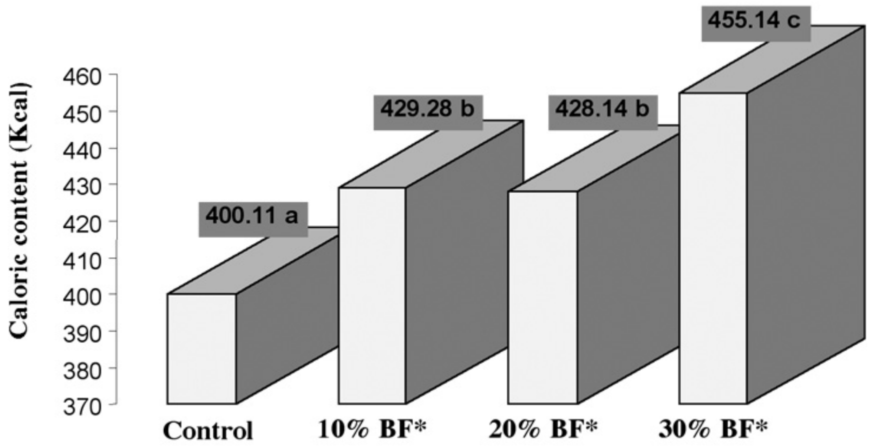

Figure 1: Caloric content (Kcal) for four different formulation of doughnuts.
Same letter on the bars of four different formulation of doughnut were not significantly different (p < 0.05)
*BF = Banana Flour

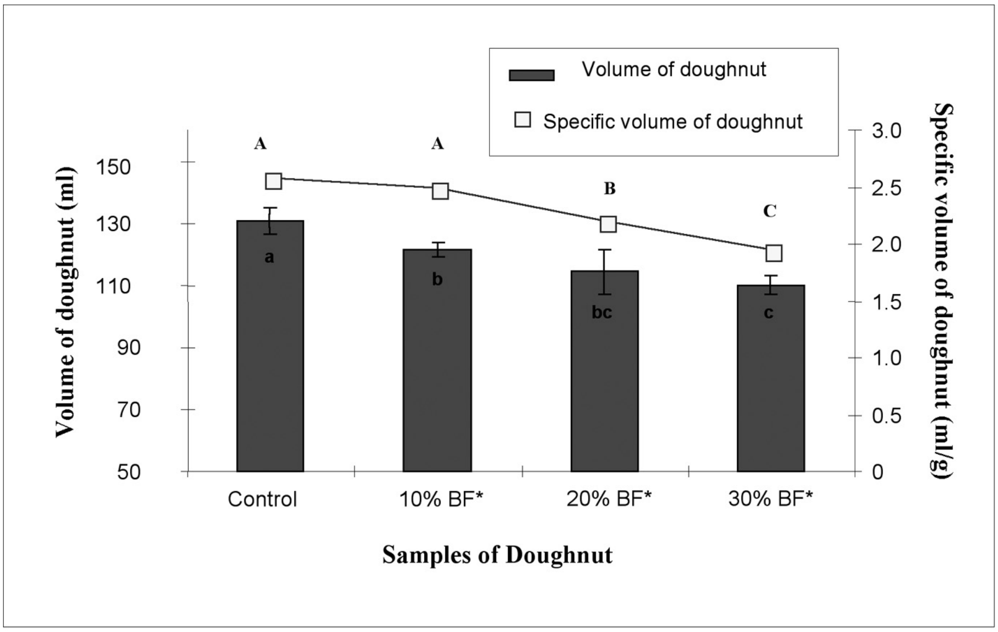

Figure 2: Volume and specific volume for four different formulations of doughnuts
Same letter on the bars and points of four different formulation of doughnut showed no significant differences (p<0.05)
*BF = Banana Flour

Table 3: Lightness (L*) and hue value of dough, crust and crumb for control and ultimate level of BF – incorporated doughnuts[#]

Sample	Dough		Crust		Crumb	
	L*	Hue value	L*	Hue value	L*	Hue value
Control	75.61±0.06[d]	87.59±0.14[d]	57.36±1.50[c]	74.07±2.57[b]	73.52±0.33[d]	88.76±0.16[d]
10% BF	71.02±0.09[c]	84.01±0.15[c]	54.52±0.43[b]	68.97±0.59[a]	69.32±0.52[c]	84.78±0.38[c]
20% BF	62.83±0.04[b]	79.73±0.16[b]	53.56±1.27[b]	70.61±2.06[a]	66.93±1.25[b]	80.04±0.88[b]
30% BF	58.96±0.06[a]	77.08±0.24[a]	51.49±1.58[a]	71.77±1.06[b]	63.83±1.81[a]	78.12±0.40[a]

Values followed by the same letter in the same column are not significantly different ($p < 0.05$)
[#]Mean ± standard deviation (n = 4)

Table 4: Measurement of sensory evaluation for control and ultimate level of Banana Flour (BF) – incorporated doughnuts*

Sample	Control	10% BF	20% BF	30% BF
Colour of crumb	2.65 ± 1.06[a]	5.53 ± 1.42[b]	6.24 ± 0.90[bc]	7.00 ± 1.17[c]
Colour of crust	3.71 ± 1.21[a]	5.82 ± 1.13[b]	6.88 ± 1.05[c]	7.12 ± 0.99[c]
Moisture of crumb	5.94 ± 1.43[a]	5.53 ± 1.70[a]	5.29 ± 1.45[a]	5.59 ± 1.91[a]
Softness of crumb	5.12 ± 1.87[a]	6.12 ±1.36[b]	6.65 ± 1.06[b]	6.95 ± 1.17[b]
Sweetness	4.59 ± 1.50[a]	4.71 ± 1.60[a]	5.12 ± 1.70[a]	5.00 ± 1.70[a]
Banana flavour	2.71 ± 1.70[a]	4.29 ± 1.40[b]	5.24 ± 1.60[b]	5.24 ± 2.20[b]
Overall acceptability	5.00 ± 1.50[a]	5.65 ± 1.41[ab]	6.71 ± 1.40[c]	6.47 ± 1.50[bc]

Values followed by the same letter in the same column are not significantly different ($p < 0.05$)
* Mean ± standard deviation (n = 20)

is due to the lower gluten content in BF compared to wheat flour. Gluten is an important component in protein which gives firmer dough matrix and manages to trap air cells to produce doughnuts with greater volume.

Ultimate increase in BF significantly ($p < 0.05$) affected the dough, crust and crumb colour (Table 3) of doughnuts. Colour evaluation showed that the dough, crust and crumb of doughnut had hue values which ranged from 68.97 – 88.76 (red – yellow quadrant). Lightness (L*) values of dough, crust and crumb were noted to decrease with increasing level of BF in the doughnut formulations. The decrease could be attributed to the higher amount of oxidized phenolic compounds formed in the BF-incorporated doughnuts during the frying process. The darker colour of crumb for BF-incorporated doughnuts than the control was due to the more compact structure of doughnut which resulted in less reflection of light. The colour of the crust contributed to the oil absorption effect and Maillard reaction between protein and inverse sugar in the presence of heat. Consequently, crust L* values for the different types of doughnuts were lower than that of the dough and crumb.

Sensory evaluation results showed that the incorporation of BF affected the colour of crumb and crust as shown in Table 4. These results correspond with the results obtained from the instrumental colour measurement. Panel scores for crumb softness decreased with increase in BF. This decrease is due to the fact that BF is rich in starch granules but lower in gluten content which results in doughnut with a harder and more compact structure. BF had no effect on the moisture of crumb and sweetness of the doughnut. The banana flavour in BF-incorporated doughnuts was found to be significantly higher ($p < 0.05$) than the control. Knuckles *et al.* (1997) reported that in sensory evaluation, products with score value of more than 5 for overall acceptability can be considered as a good quality product. Doughnut with 20% BF was found to be the most acceptable and was significantly higher ($p < 0.05$) in score value than the control and 10% BF-incorporated doughnut.

CONCLUSION

Substitution of wheat flour with BF in doughnut indicated an increased in TDF content and can be classified as good fibre sources due to the significantly higher dietary fibre content in the BF doughnuts (10% BF : 5.51%, 20%BF: 6.56%, 30%BF: 6.89%) as compared to the control (3.07%). Doughnut with 20% BF was significantly different ($p < 0.05$) in overall acceptability compared to the control and 10% BF doughnuts. Therefore, acceptable doughnut can be prepared by substituting wheat flour with 20% BF.

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