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Quality evaluation of steamed wheat bread substituted with green banana flour

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Abstract: Quality attributes of steamed bread without green banana flour (BF) (CON), substituted with 30% BF (BBFI) and 30% BF + 8% gluten (BBFII) were determined. The green banana flour (BF) and the mixture of wheat flour (WF) substituted with 30% BF + 8% gluten (FBFII) was significantly highest in water holding capacity and oil holding capacities, respectively. Potassium, calcium and magnesium were significantly higher in BBFI and BBFII than CON. Significantly highest insoluble dietary fibre and total dietary fibre shown in BBFI. Steaming resulted significant reduction in resistant starch content in BBFI as compared with the dough of BBFI I. The specific volume of BBFII and CON showed significant different compared to the BBFI. The BBFII spread ratio was significantly highest and steamer spring lowest than CON. BBFII showed significantly highest in hardness and adhesiveness values but CON was significantly highest in cohesiveness, elasticity and chewiness. L and Hue values was shown highest in CON. BBFII indicated highest acceptability score than other samples.

Keywords: Banana, gluten, proximate composition, resistant starch, dietary fibre

Introduction

Steamed bread is very popular in the South-East Asian regions of the world. It originated in China thousand of years ago and is a widely consumed breakfast item in the general households. During its long-term development, numerous unique types of steamed bread have appeared, among which the most representative types includes: Northern-style and Southern-style steamed bread (Fan *et al*., 2009). Steamed bread is formulated with wheat flour (WF), water and commercial yeast. One of the major applications of wheat in China is the production of steamed bread, which represents about 40% of the wheat consumption (He *et al*., 2003). According to He et al. (2003), the quality of steamed bread is positively correlated with the protein content and gluten strength.

Banana is mainly produced in tropical and sub-tropical developing countries. About one fifth of the entire banana harvested is wasted, and the rejected bananas are normally disposed. Green banana flour (BF) is a low-cost ingredient for food industry and an alternative to minimizing banana wastes (Zhang *et al*., 2005). According to the available reports, green banana is rich in starch and its flour contains 61.3-76.5 g/100 g of starch (dry weight) and has high fibre content (6.3-15.5 g/100 g) (dry weight) (Mota *et al*., 2000; Juarez-Garcia *et a*l., 2006). A high dietary fibre intake has been reported to have beneficial effects on human health (Champ and Guillon, 2000). Increasing dietary fibre intake increases fecal softness, fecal bulk, water binding capacity, organic binding capacity and reduces intestinal transit time, all of which enhance removal of stagnant or potentially detrimental materials from the bowels. Increased fermentation in the large intestine also produces an environment healthier for the colonic structure (AACC, 2001).

According to available reports (Goni *et al*., 1996; Anil, 2007), WF contains very low total dietary fibre (2.7% dry basis) and resistant starch (≤1% dry matter) contents, which are lost during WF refinement process. In addition, till date, there are no reports on the utilization of banana flour (BF) in making steamed bread. Earlier, the attention of researchers were focused on BF incorporated bread and pasta (Juarez-Garcia *et al*., 2006; Ovando-Martinez *et al*., 2009). According to them, the crude fibre, ash, and resistant starch content of BF incorporated products were higher than that control without addition of BF. Thus, the substitution of BF (which has been proved to contain high sources of fibre and essential nutrients) into the bakery products can be suitable for enhancing health. Hence, the BF may have potential as an ingredient in making steamed bread.

The present study was conducted to evaluate the effects of WF substitution with green banana flour with addition of gluten in steamed bread in terms of the functional, physicochemical and sensory

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attributes.

Materials and Methods

Preparation of banana flour

Matured green bananas (Musa acuminata x balbisiana cv. Awak) were obtained from a local market in Penang, Malaysia. The selected bananas showed had no traces of yellowness/ripeness. The green bananas were peeled and soaked in sodium metabisulphite (0.2%) solution for 30 min to prevent browning. The bananas were then sliced manually (1.5 mm) followed by oven-drying (AFOS, Model mini, No. CK 80520, England) at 60°C for 12 h.

Further, the dried slices of banana were blended in a blender (Moulinex Super Blender Mill 2, 720). The powder was then further grind in a Bench Top Grinder (Micro Universal Bench Top Grinder, Type ZM 100, Germany) and sieved through 60-mesh size sieve. The banana flour was then packed in an airtight container and stored at room temperature prior to use.

Preparation of steamed bread

Steamed bread was prepared according to the method adopted in local food industries (Mauripan Sdn. Bhd., Penang, Malaysia). For the preparation of bread, all the ingredients (wheat flour, yeast, sugar, shortening, salt and gluten) were purchased from Sim Company Sdn. Bhd., Penang, Malaysia. The substitution of 30% wheat flour with green banana flour was prepared firstly by making the water-sugar suspension. Then, flour, yeast, salt and gluten were mixed with the sugar solution in a mixing bowl and followed with addition of shortening. The dough was optimally mixed using the mixer (Kitchen Aid-KSM 900, USA) for about 10 to 15 min until the dough became soft and elastic.

After mixing, 30 g of the samples was weighed individually and molded into a shape manually. The molded dough was placed on a greased tray for further proofing in a proofer (Bakbar, model: E87, England) at 30 ± 1°C. After 45 min, the dough were placed on a tray and steamed for 10 min in a steamer. The cooked steamed breads were cooled before further testing.

Water holding capacity (WHC) and oil holding capacity (OHC)

The method described by Giami *et al*. (1994) was used to determine WHC and OHC of the WF, BF and steamed bread. In brief, 10 ml of distilled water (for WHC) or the commercial corn oil (for OHC) (Mazola, Unilever, Malaysia Holding Sdn. Bhd.) (density = 0.920 g/ml) were added to one gram of dry flour samples. The mixture was shaken using vortex (Boeco, Germany) for two minutes and then left at room temperature for 30 min. The mixture was then centrifuged at 5000 g speed for 20 min. The residues obtained after centrifugation were weighed for WHC and OHC calculation.

Proximate analysis

Moisture content, crude protein, crude fat, ash and crude fibre content was determined using oven drying (AOAC method 977.11), Kjeldahl's (AOAC method 955.04), Soxhlet (AOAC method 960.39), dry ashing (AOAC method 923.03) and gravimetric methods (AOAC method 991.43), respectively (AOAC, 1995). Carbohydrate was calculated by difference: carbohydrate = [100 – (moisture + crude protein + crude fat + ash + crude fibre)].

Determination of total dietary fibre

The total Dietary Fibre Assay Kit (TDF-100A; Sigma-Aldrich, St. Louis, Missouri, USA) based on the enzymatic-gravimetric method published in the AOAC (AOAC, 2000) was used to determine total dietary fibre (TDF), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF). This method involved gelatinization of the defatted samples with stable heat and α-amylase (A 3306). The samples were enzymatically digested with protease (P 3910) followed by amyloglucosidase (A 9913) to remove the protein and starch content in the sample. Insoluble dietary fibre was recovered with filtration. Soluble dietary fibre was precipitated with ethanol and filtered.

Determination of resistant starch (RS)

RS was measured according to the method described by Goni *et al*. (1996). Protein was removed with pepsin (P-7012, 2,500-3,500 units/mg protein; Sigma Chemical Co., St Louis, MO, USA) at 40 ^{o}C for 1 h. Then the sample was incubated with α-amylase (A-3176, 10-30 units/mg solid; Sigma Chemical Co.) at temperature 37^{o}C for 16 h. to hydrolyse digestible starch. Treatment of the residue with 2M KOH to solubilize resistant starch and finally incubation with amyloglucosidase (A 9913) at the pH 4.75, temperature 60^{o}C for 45 min. to hydrolyse the resistant starch. The glucose content was determined by using a glucose oxidase/peroxidase assay. RS was calculated as glucose (mg) x 0.9 [0.9 = corrected factor (glucose-polysaccharide)].

Mineral composition determination

Minerals were determined by the modified method of James (1995) with slight modifications. In brief, one gram of the dry sample was dissolved in 6 ml HNO_3 and 1 ml 30% hydrogen peroxide to determine

Copper (Cu), Iron (Fe), Zinc (Zn), Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) with using atomic spectrophotometer (Perkin Elmer model 5100 PC). Absorbance was recorded and a standard curve was plotted. Meanwhile, phosphorus (P) content was determined using colorimetric method. Results were expressed in mg/100g sample.

Specific volume, spread ratio and steamer-spring determination

The specific volume (ml) was determined using rapeseed displacement method; specific volume (cm3/g) was calculated by dividing volume (ml) by weight (g) and the spread ratio was determined by dividing width (cm) by height (cm) [AACC Method No. 55-50] (AACC 2000). The steamer-spring (cm) analysis was calculated by the differences between steamed bread height before and after steaming (Rubenthaler *et al*., 1992).

Texture profile analysis

Texture of the steamed bread was measured by using TA (Texture Analyser-XT2; version 1.05 Table Microsystem Ltd, UK) with a measure force in compression test selected. The instruments included P1.51 1.5 inches DIA aluminum cylinder probe and grain gage sensitive plat. These instruments were connected to the Texture Expert computer program to analyze the data. The parameters determined were hardness, cohesiveness, elasticity, chewiness and adhesiveness. The texture profile analysis was done according to the method of AACC 74-09 (AACC, 2000).

Colour measurements

Colour measurements (L*, C* and H values) of the banana flour incorporated steamed breads and the CON sample (control, without addition of BF) were carried out within 1 h after steaming using the Minolta 3500d Colorimeter Osaka, Japan. Each sample was place on the plate (CM-A128). A ‘Target Mask’ (CM-A126) was used to limit the illumination area to actual area of the plate. Illuminant D65 was used. The instrument was calibrated with a calibration zero box (CM-A120) followed by a white dish (CM-A120).

Sensory evaluation

The sensory attributes of the CON (control) and the BF incorporated steamed bread were evaluated by 35 panelists comprising of trained students/researchers of the Food Technology Division, Universiti Sains Malaysia. All samples were evaluated using a nine point Hedonic Scale with “9” equaling to “like extremely and “1” equaling to “dislike extremely”. The parameters evaluated by the panelists included colour, taste, off-flavor, texture and overall acceptance.

Statistical analysis

Statistical analyses were carried out using the Statistical Package for the Social Science (SPSS) for analyses of variance (ANOVA) and Tukey’s test was used to compare the mean score. Significance was defined at $P<0.05$ using the Tukey’s test. Three replications were performed for all the analyses.

Results and Discussion

Water holding capacity (WHC) and oil holding capacity (OHC)

Table 1 shows the results on the WHC and OHC of WF, BF, FBFI and FBF II (BF with the addition of gluten). There were significant differences ($P< 0.05$) recorded between WHC of WF (84%) and BF (161%). Results indicated that dietary fibre from BF is able to bind or entrap more water than WF. The high WHC of fibre rich flour is attributed to the higher number of hydroxyl groups found in the fibre structure, which tends to allow more water interactions through hydrogen bonding, as reported previously by Rosell *et al*. (2001). Addition of 8% gluten and BF into the formulation did not affect WHC, as compared to BBFI. The interaction between the hydrogen and disulphide bonds still remains unclear. However, further studies are vital to identify the interaction between bonding found in both BF and gluten, which might provide more details.

The OHC of WF (88%) showed non-significant differences ($P > 0.05$) from BBFI (83%) and BBFII (90%). However, all of these samples were found to be significantly higher ($P< 0.05$) than BF (72%). This might be attributed to the presence of protein content in WF which is a hydrophobic material that could result in more available hydrophobic binding sites available for oil holding by the protein (Heywood *et al*., 2002). BF could be used for stabilizing emulsions of food system, as well as being a good source of dietary fibre.

Proximate composition

The proximate composition of different types of steamed bread prepared in this study is presented in Table 2. Results indicated that BBFII (32.89%) to have significantly higher ($P< 0.05$) moisture content than the CON (30.97%) and BBFI (31.69%). This might be attributed to good WHC of BF and gluten. Several researches have also reported an increase in moisture content of breads supplemented with non-

Table 1. Water holding capacity and oil holding capacity of different flour mixtures

	WF	BF	FBFI	FBFII
WHC (%)	84 ± 0.01^a	161 ± 0.02^c	111 ± 0.06^b	101 ± 0.04^b
OHC (%)	88 ± 0.02^b	72 ± 0.02^a	83 ± 0.02^b	90 ± 0.04^c

For each parameter in a row, values with the same letters are not different significantly (*P > 0.05*).
WHC= water holding capactiy; OHC= oil holding capacity; WF= wheat flour; BF= banana flour; FBFI= mixture of WF substituted with 30% BF; FBFII= mixture of WF substituted with 30% BF + 8% gluten.
*Values are means ± standard deviations.

Table 2. Proximate analysis of the steamed breads*

Composition (%)	CON	BBFI	BBFII
Moisture	30.97 ± 0.21^a	31.69 ± 0.15^b	32.89 ± 0.40^c
Ash	0.82 ± 0.02^a	0.94 ± 0.06^a	0.91 ± 0.08^a
Fat	3.16 ± 0.09^a	3.07 ± 0.26^a	4.47 ± 0.59^b
Crude fibre	0.95 ± 0.51^a	1.90 ± 0.37^{ab}	2.39 ± 0.41^b
Protein	8.39 ± 0.27^b	5.72 ± 0.40^a	8.75 ± 0.21^b
#Carbohydrate	55.71 ± 1.03^b	56.68 ± 0.55^b	50.59 ± 0.46^a

For each parameter in a row, values with the same letters are not different significantly (P > 0.05).
CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.
. *Values are means ± standard deviations.
Result obtained by difference.

Table 3. Insoluble dietary fibre, soluble dietary fibre and total dietary fibre content of steamed breads*

	CON	BBFI	BBFII
IDF (%)	1.38 ± 0.19^a	5.15 ± 1.50^b	3.17 ± 0.90^{ab}
SDF (%)	0.86 ± 0.10^b	0.50 ± 0.22^{ab}	0.47 ± 0.05^a
TDF (%)	2.24 ± 0.11^a	5.65 ± 1.31^b	3.64 ± 0.99^{ab}

For each parameter in a row, values with the same letters are not different significantly (P > 0.05).
IDF= insoluble dietary fibre; SDF= soluble dietary fibre; TDF= total dietary fibre; CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.
*Values are means ± standard deviations.

Table 4. Resistant starch content of dough and steaming steamed breads*

Samples	RS (%)
DCON	2.64 ± 0.21^a
DBFI	10.57 ± 0.31^c
DBFII	10.37 ± 1.58^c
CON	2.07 ± 0.07^a
BBFI	5.42 ± 2.06^b
BBFII	9.54 ± 0.27^c

For each parameter in a column, values with the same letters are not different significantly (P > 0.05).
DCON= dough CON; DBFI= dough BBFI; DBFII= Dough BBFII; CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.
RS= resistant starch.
*Values are means ± standard deviations.

wheat flours (pumpkin powder and jackfruit seed flour) (Ptitchkina *et al*., 1998; Tulyathan *et al*., 2002). Ash content of the 3 types steamed bread did not show any significant differences (P> 0.05). Steamed bread incorporated with 30% of BF with the addition of 8% gluten was found to be significantly high in fat, which can be related to the high protein content of the BBFII, which is contributed from the addition of wheat gluten. According to Heywood *et al*. (2002), protein and wheat gluten has more hydrophobic binding sites which are usually available for binding hydrophobic substances.

Additions of gluten significantly affected the crude fibre content of steamed bread (2.39%), which was significantly higher (P< 0.05) than the CON (0.95%). This might be attributed to the high fibre (1.26%) of green banana flour (Juarez-Garcia *et al*., 2006). Both CON (8.39%) and BBFII (8.75%) contained significantly higher (P< 0.05) protein than BBFI (5.72%). The protein of BBFII was comparable to the CON, which might be attributed to the addition of gluten. The reduction in protein content of BBFI might have resulted from the dilution of gluten as WF was substituted with BF in the steamed bread. Addition of gluten into the formulation resulted in a subsequent reduction of carbohydrate in BBFII.

Dietary fibre determination

The CON and BF incorporated steamed bread were analyzed for the TDF, SDF and IDF contents. The results are presented (as % dry weight basis) in Table 3. The BBFI significantly increased in TDF in comparison with the CON. The high content of TDF in BBFI might have resulted from high IDF content of BF. According to Sidhu *et al*. (1999), wheat flour is a poor source of dietary fibre, because the bran fractions that are high in TDF contents are removed during the milling process. However, the BBFII (3.64%) was found to be slightly lower in TDF contents than the BBFI (5.65%).

IDF content of steamed bread show similar trend as TDF content. The BBFI samples (5.15%) contained higher IDF than the CON (1.38%). The higher content of IDF in BBFI than the CON is in agreement with the previous report of Wang *et al.* (2002). Results indicated BBFII (0.47%) has significantly low (P< 0.05) SDF content than the CON (0.86%). The lower SDF than IDF value might be attributed to the hydrolysis of SDF by yeast enzymes or losses occurring during steaming. This observation can be attributed to the high content of hemicelluloses (type of IDF) present in BF (Mota *et al*., 2000).

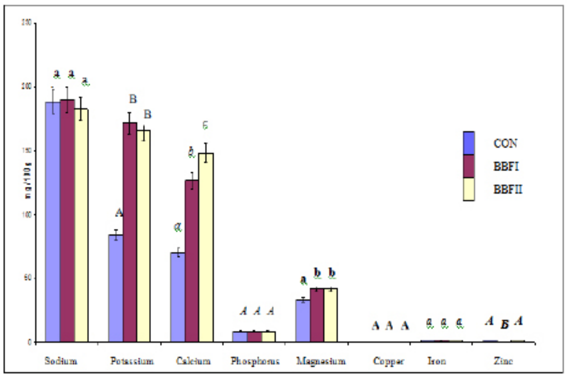

Figure 1. Mineral composition of steamed breads
For each parameter, with the same letters are not different significantly (*P > 0.05*).
CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.

Table 5. Specific volume, spread ratio and steamer spring of steamed breads*

	CON	BBFI	BBFII
Specific volume (ml/g)	4.20 ± 0.17^{b}	3.67 ± 0.02^{a}	4.27 ± 0.06^{b}
Spread ratio	2.05 ± 0.05^{a}	2.11 ± 0.32^{a}	2.26 ± 0.31^{b}
Steamer spring (cm)	0.55 ± 0.05^{c}	-1.00 ± 0.00^{a}	-0.17 ± 0.06^{b}

For each parameter in a row, values with the same letters are not different significantly (P > 0.05).
CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.
*Values are means ± standard deviations.

Resistant starch determination

The dough with 30% mixture of BF (DBFI), dough with 30% mixture of BF with added 8% gluten (DBFII) and BBFI and BBFII had higher levels of RS (10.57, 10.37, 5.42 and 9.54%, respectively) compared to the dough of control without addition of BF (DCON) and CON (2.64 and 2.07%, respectively) as shown in Table 4. This might be attributed to the high starch contents in the green banana (70-80% on dry weight basis) (Zhang *et al*., 2005). The high level of RS content in BF steamed bread was also associated with the presence of high level of insoluble residue of dietary fibre in the BF steamed bread as described earlier (Table 3). From this result application of BF can be used an alternative in product formulation for high RS.

BBFI was low in RS content (5.42%) than DBFI (10.57%). The present of raw starches in green banana flour is classified as RS2 (RS type II, ungelatinized starch granules) are found to be resistant to attack by acid and enzyme. This is attributed to the raw starch in green banana flour which has crystalline properties that protect the starch from being digested (FAO, 1998). According to Ang (2005), these crystalline properties can be lowered by heating process for starch to gelatinize. Therefore, the cooking process can reduced the resistant starch content in green banana flour. Substitution of 8% gluten into the steamed bread was found to increase the RS content (9.54%) as compared to the steamed bread without addition of gluten (5.42%).This showed that the starch of wheat gluten resists the attack by α-amylase.

Mineral composition

Figure 1 show the relative concentration of minerals (mg/100 g) in different type of steamed bread. No significant difference (P> 0.05) in Na was recorded among the samples. Potassium content of BBFI (172.6 mg/100g) and BBFII (164.9 mg/100g) was significantly higher (P< 0.05) than the CON (85.4 mg/100g) which might be attributed to the abundance in K element in the banana (Happi Emaga *et al.*, 2007). The mineral content is associated with the ash content. The BF incorporated steamed bread added with gluten provides a good source of K. The trace elements like Cu and Fe did not show significant differences (P> 0.05) between the samples, but Zn content of the CON and BBFII were significantly higher (P< 0.05) than BBFI. The Zn content in the steamed bread decreased slightly after substituted with 30% of BF.

Specific volume, spread ratio and steamer-spring determination

The results on the texture of steamed bread samples in terms of specific volume, spread ratio and steamer-spring are shown in Table 5. Quality of steamed bread was significantly reduced by 30% substitution of BF. Volume of BBFI (3.67 ml/g) decreased as compared to CON (4.20 ml/g). This can be attributed to the dilution of gluten as reported earlier by Pomeranz et al. (1977). This change can also be due to interaction between gluten and fibre material (Chen *et al*., 1988). The reductions were comparable to those previously reported with added carob fibre, inulin and pea fibre and rice straw (Wang *et al*., 2002; Sangnark and Noomhorn, 2004). However, the specific volume of BBFII (4.27 ml/g) did not show any significant differences (P> 0.05) compared to CON.

The spread ratio of the BBFII (2.26) was significantly higher than CON (2.05) and BBFI (2.11), which might be attributed to the addition of gluten where interaction of gluten with water occurs resulting in higher spreader ratio of the steamed bread. Increase in the gluten network of the dough and the increases in ability of the dough to hold the gasses results in high expansion of the dough. According to He *et al*. (2003), protein content and gluten strength are the most important factors that determines the steamed bread quality. Thus, the addition of gluten into the steamed bread ingredient might give a better

Table 6. Texture profile analysis of steamed breads*

	CON	BBFI	BBFII
Hardness (N)	2.31 ± 0.40ᵃ	2.77 ± 0.50ᵃ	3.06 ± 0.21ᵇ
Cohesiveness (Ns/N)	0.50 ± 0.03ᵇ	0.37 ± 0.03ᵃ	0.40 ± 0.01ᵃ
Elasticity (s)	0.88 ± 0.06ᵇ	0.53 ± 0.08ᵃ	0.43 ± 0.07ᵃ
Chewiness (N)	1.00 ± 0.15ᵇ	0.55 ± 0.14ᵃ	0.60 ± 0.10ᵃ
Adhesiveness (Ns)	0.03 ± 0.02ᵃ	0.04 ± 0.03ᵃ	0.08 ± 0.01ᵇ

For each parameter in a row, values with the same letters are not different significantly (P > 0.05).
CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.
*Values are means ± standard deviations.

Table 7. Mean value of colour indices of the steamed breads*

	CON	BBFI	BBFII
*L**	87.55 ± 0.11ᵇ	76.64 ± 0.20ᵃ	76.86 ± 0.04ᵃ
*C**	13.61 ± 0.25ᵃ	15.91 ± 0.18ᵇ	15.91 ± 0.15ᵇ
H	90.72 ± 0.45ᶜ	78.66 ± 0.26ᵃ	80.61 ± 0.20ᵇ

For each parameter in a row, values with the same letters are not different significantly (*P > 0.05*).
L= lightness; C= chroma; CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.
*Values are means ± standard deviations.

quality of the steamed bread.

The steamer-spring of CON (0.55 cm) and BBFII (-0.17 cm) showed highest value than BBFI (-1.00 cm). In this investigation (P< 0.05), the results indicated that steamer-spring to be significantly reduced with substitution of 30% BF into the steamed bread. Hoseney (2004) have reported that there is an interaction in the dough that makes it more elastic and resulted in the gas continuous-sponge structure of bread after steaming. However, gluten content can also be reduced by other components such as: non-wheat flour and dietary fibre (Sangnark and Noomhorn, 2004). The addition of gluten for the preparation of steamed bread did not improve the steamer-spring of the product. This is attributed to higher strength of dough formed when gluten was added into the 30% green banana flour. According to Rosell *et al*. (2001), high dough strength can promote an increase in loaf volume but dough development can be hindered when dough is too strong. Moreover, shrinkage of the end-product might occurred due to the excessive in elasticity. However, too high extensibility may resulted in a flat-shaped product (Hou & Popper, 2007).

Texture profile analysis

Hardness of the steamed bread incorporated with 30% of BF (2.77 N) showed no significantly differences (P> 0.05) with CON (2.31 N) (Table 6). Gluten added steamed bread increased the hardness value of the steamed bread (3.06 N) as compared to both CON and BBFI, which might attributed to the high water absorption of gluten. Sangnark and Noomhorn (2004) reported that high fibre ingredients added into bread formulation increases the hardness of bread. Similar trend was also observed in the adhesiveness where BBFII (0.08 Ns) had significantly higher (P< 0.05) adhesiveness than BBFI (0.04 Ns) and CON (0.03 Ns).

The elasticity of CON (0.88 s) was significantly higher (P< 0.05) than BBFI (0.53 s) and BBFII (0.43 s). The highest value of the elasticity of CON among the samples can be attributed to the reduction of wheat flour resulting from dilution of gluten structure formation in BBFI and BBFII. This reduction in gluten structure contributes to the reduction in elasticity. Addition of 8% gluten into the steamed bread did not have any effect on the elasticity of steamed bread. It can be concluded that BF affects the gluten network of the dough and reduces the ability of dough to hold gasses, which results low elasticity and expansion of the dough (Pyler, 1973). In this study, the cohesiveness and chewiness decreased with substitution of BF in wheat steamed bread, CON (0.5 Ns/N), BBFI (0.37 Ns/N), BBFII (0.4 Ns/N) and CON (1.00 N), BBFI (0.55 N), BBFII (0.60 N), respectively. Gluten content was also reduced by other components, such as non-wheat flour and dietary fibre which cause an adverse effect on the steamed bread texture.

Colour measurements

The effects of added BF and gluten on the colour of steamed bread are shown in Table 7. Significant differences (P< 0.05) were observed in L* (lightness) and C* (chroma) values between CON, BBFI and BBFII. In L* value, the CON (87.55) showed higher value as compared to the BBFI (76.64) and BBFII (76.86). The results indicated that both BBFI and BBFII were darker than CON. The fibre and gluten added influenced the steamed bread colour. The darkness of both samples was resulted from Maillard reaction between reducing sugar and protein (Mohamed et al., 2009). Similar observations were also done by earlier researchers (Sangnark and Noomhorm, 2004; Anil, 2007; Mohamed *et al*., 2009) wherein, substitution of high dietary fibre flour into the bread resulted in dark colour. The H (hue) value of the CON (90.72), BBFI (78.66) and BBFII (80.61) showed significant difference from each other. The H value of three types of steamed bread was nearer to the yellow quadrant.

Sensory evaluation

Sensory evaluation (Figure 2) indicated that the

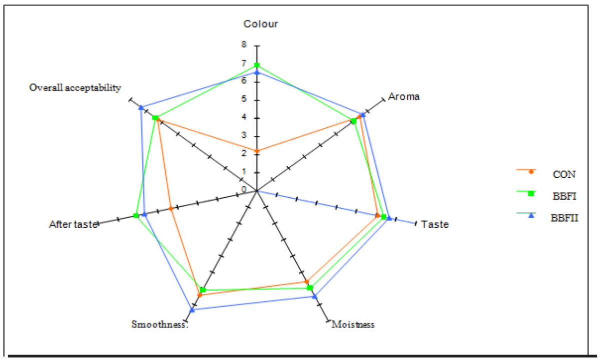

Figure 2. Spider plot of the breads supplemented with different ingredients.
CON= without BF; BBFI= 30% BF; BBFII= 30% BF +8% gluten.

colour of the BBFI (score 7.00) to be significantly higher (P< 0.05) among all the samples. However, the CON bread had the lowest score (2.20) in colour. Results from sensory evaluation revealed the panelists to prefer for the darker colored steamed bread. The aroma and taste of the BBFI and BBFII were not significantly different (P> 0.05) with CON. Incorporation of BF up to 30% in the formulation did not affect the aroma and taste of steamed bread products. Furthermore, the panelists found BBFII to score highest in terms of moistness (score 6.53) and smoothness (score 7.33). Whereas, BBFI scored lowest for smoothness (score 6.0), which might be attributed to the high fibre contents. The score for 'after taste' in BBFI (score 6.48) and BBFII (score 6.0) were significantly higher than CON (score 4.48). The after taste in the steamed bread might have resulted from the incorporation of BF into steamed bread.

Overall, the CON, BBFI and BBFII showed no significant differences (P> 0.05) in the overall acceptability. Hence, substitution of 30% BF and with or without the addition of 8% gluten into the steamed bread has high potential for marketability of bakery products with added nutritional value.

Conclusions

Green BF had higher WHC and lower OHC than WF. BBFI and BBFII showed significantly increased in moisture, fat, crude fibre, IDF, TDF and essential minerals (K, Ca, Mg and Zn). BBFI and BBFII showed better quality steamed bread in terms of specific volume and spread ratio but it resulted in darker colour than CON. Thus, green BF has high potential as value added ingredient incorporated in steamed bread formulation.

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References

AACC 2000. AACC International Approved Methods of Analysis.

AACC 2001. American Association Of Cereal Chemists. The definition of dietary fiber. Cereal Food World 46: 112-126.

Ang, H. H. 2005. Fast facts on dietary fibre. Malaysia: Beribu Juru Sdn. Bhd.

Anil, M. 2007. Using of hazelnut testa as a source of dietary fiber in breadmaking. Food Engineering 80: 61-67.

AOAC 1995. Official Method of Analysis. Washington: Association of Official Analytical Chemistry.

AOAC 2000. Official Method of Analysis. 17th Edition. Washington: Association of Official Analytical Chemistry.

Champ, M. and Guillon, F. 2000. Structural and physical properties of dietary fibres, and consequences of processing on human physiology. Food Research International 33: 233-245.

Chen, H., Rubenthaler, G. L. and Schanos, E. G. 1988. Effect of apple fiber and cellulose on the physical properties of wheat flour. Journal of Food Science 53: 304-305.

Fan, Y. D., Sun, H. Y., Zhao, J. L., Ma, Y. M., Li, R. J. and Li, S. L. 2009. QTL mapping for quality traits of northern-style hand-made Chinese steamed bread. Cereal Science 49: 225-229.

FAO. 1998. Food and Agriculture Organization of the United Nations. Carbohydrates in human nutrition. FAO Food and nutritional papers-66. Rome, Italy: Agriculture and consumer protection.

Giami, S. Y., Okonkwo, V. I. and Akusu, M. O. 1994. Chemical composition and functional properties of raw, heat-treated and partially proteolysed wild mango (*Irvingia gabonensis*) seed flour. Food Chemistry 49: 237-243.

Goni, I., Garcia-Alonso, A. and Saura-Calixto, F. 1996. Analysis of resistant starch: a method for foods and food products. Food Chemistry 56: 445-449.

Happi Emaga, T., Herinavalona Andrianaivo, R., Wathelet, B., Tchango Tchango, J. and Paquot, M. 2007. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. Food Chemistry 103: 590-600.

He, Z. H., Liu, A. H., Pena, R. J. and Rajaram S. 2003. Suitability of Chinese wheat cultivars for production of northern style Chinese steamed bread. Euphytica 131: 155-163.

Heywood, A. A., Myers, D. J., Bailey, T. B. and Johnson, L. A. 2002. Functional properties of low-fat soy flour produced by an extrusion-expelling system. Journal of the American Oil Chemists' Society 79: 1249-1253.

Hoseney, R. C. 2004. Yeast-leavened products. In principles of cereal science and technology. 2nd Edition. St. Paul, MN: American Association of Cereal Chemistry.

Hou, G. G. and Popper, L. 2007. Chinese steamed bread. In Popper, L., Schäfer, S. and Freund, W. (Eds.). Future of flour-A compendium of flour improvement, p.309-318. Clenze: Verlag Agrimedia GmbH.

James, C. S. 1995. Analytical chemistry of foods. Glasgow: Blackie Academic and Professional.

Juarez-Garcia, E., Agama-Acevedo, E., Sáyago-Ayerdi, S. G., Rodriguez-Ambriz, S. L. and Bello-Perez, L. A. 2006. Composition, digestibility and application in breadmaking of banana flour. Plant Foods for Human Nutrition 61 (3): 131–137.

Mohamed, A., Xu, J. and Singh, M. 2009. Yeast leavened banana-bread: Formulation, processing, colour and texture analysis. Food Chemistry 118: 620-626.

Mota, R. V., Lajolo, F. M., Ciacco, C. and Cordenunsi, B. R. 2000. Composition and functional properties of banana flour from different varieties. Starch/Stärke 52: 63–68.

Ovando-Martinez, M., Sayago-Ayerdi, S., Agama-Acevedo, E., Goni, I. and Bello-Perez, L. A. 2009. Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. Food Chemistry 113: 121-126.

Pomeranz, Y., Shogren, M. D., Finney, K. F. and Bechtel, D. B. 1977. Fiber in breadmaking- effects on functional properties. Cereal Chemistry 54: 25-41.

Ptitchkina, N. M., Norokreschonova, L. V., Piskunova, G. V. and Morris, E.R. 1998. Large enhancements in loaf volume and organoleptic acceptability of wheat bread by small additions of pumpkin powder: possible role of acetylated pectin in stabilizing gas cell structure. Food Hydrocolloids 12: 333-337.

Pyler, L. 1973. Baking science and technology. USA: Siebel Publishing Company.

Rosell, C. M., Rajas, J. A. and Benedito de Barber, C. 2001. Influence of hydrocolloids on dough rheology and bread quality. Food Hydrocolloids 15 (1): 75-81.

Rubenthaler, G. L., Pomeranz, Y. and Huang, M. L. 1992. Steamed bread IV. Negative steamer-spring of strong flour. Cereal Chemistry 69 (3): 334-337.

Sangnark, A. and Noomhorn, A. 2004. Chemical, physical and baking properties of dietary fibre prepared from rice straw. Food Research International 37: 66-74.

Sidhu, J. S., Al-Hooti, S. N. and Al-Saqer, J. 1999. Effect of adding wheat bran and germ fractions on the chemical composition of high-fiber toast bread. Food Chemistry 67: 365-371.

Tulyathan, V., Tananuwong, K., Songjinda, P. and Jaibon, N. 2002. Some physicochemical properties of jackfruit (*Artocarpus heterophyllus Lam.*) seed flour and starch. Science Asia 28: 37-41.

Wang, J., Rosell, C. M. and Benedito de Barbe, C. 2002. Effect of the addition of different fibres on wheat dough performance and bread quality. Food Chemistry 79: 221-226.

Zhang, P., Whistler, R. L., BeMiller, J. N. and Hanaker, B. R. 2005. Banana starch: production, physicochemical properties and digestibility – a review. Carbohydrate Polymers 59: 443–458.