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Effects of banana flour and β-glucan on the nutritional and sensory evaluation of noodles

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ABSTRACT

The purpose of this study is to determine the nutritional and sensory attributes of the yellow alkaline noodle (YAN) prepared from 30% matured green banana (*Musa acuminata* × *balbisiana Colla* cv. *Awak*) flour (BF) and with addition of 10% oat β-glucan. The substitution of wheat flour with BF resulted in significantly ($p < 0.05$) higher total dietary fibre (TDF), and especially insoluble dietary fibre (IDF), resistant starch (RS) and total starch contents. Thirty percent of BF significantly ($p < 0.05$) improved the antioxidant properties (AP) of noodles in terms of the total phenolic (TP) content and inhibition of peroxidation. Noodle incorporated with 30% BF and added oat β-glucan showed the lowest GI and carbohydrate digestibility rate, and higher concentrations of essential minerals (magnesium, calcium, potassium and phosphorus) and proximate components, with the exception of crude fat, when compared to the control. Sensory evaluation indicated that the quality of the 30% BF-substituted noodle was comparable to the control.

1. Introduction

The world is seeing a dramatic increase in the problem of over-nutrition, especially among children in many western and developing Asian countries, as a result of economic development. According to the WHO (2005), 35 million people died from chronic diseases in 2005. The over-nutrition diet is related to an increase in chronic diseases, obesity, cardiovascular disease, type-2 diabetes and constipation.

Noodle products are the staple food in many parts of Asia. Traditional noodle is made from simple ingredients (wheat flour, water and salt) and is claimed to lack other essential nutritional components, such as dietary fibre, vitamins and minerals, which are lost during wheat flour refinement (Maberly, 2003). Thus, noodle products which represent a major end-use of wheat, are suitable for enhancing health after incorporating sources of fibre and essential nutrients.

Green banana (*Musa acuminata* × *balbisiana Colla* cv. *Awak*) is high in total dietary fibre content, especially in hemicellulose. Apart from dietary fibre, bananas contain high amounts of essential minerals, such as potassium, and various vitamins, e.g., A, B_1, B_2 and C. Matured green plantain is very rich in resistant starch which is resistant to α-amylase and glucoamylase due to its high degree of crystalline intrinsic structure (Zhang, Whistler, BeMiller, & Hamaker, 2005).

The soluble fibre has been reported to have positive effects on glycaemic, insulin and cholesterol responses to foods. Beta glucan (β-glucan), derived from oat (*Avena sativa* L.), is a type of soluble fibre which could form a viscous solution in the digestive system. The Food and Drug Administration (FDA) had claimed that foods containing 0.75 g β-glucan or 1.7 g of soluble fibre per serving can reduce the risk of heart disease (FDA, 2001).

Antioxidant compounds show strong protective effects against certain diseases, such as cancer, rheumatoid arthritis and cardiovascular disease (Clifford, 1995; Hertog, Feskens, Hollman, Katan, & Kromhout, 1993). Banana and plantain are well known as tropical fruits that contain various antioxidants, especially catechin, epicatechin, gallocatechin (Someya, Yoshiki, & Okubo, 2002). Abundant phenolic compounds (peel, 907 mg/100 g dry sample; pulp, 232 mg/100 g dry sample) were found in *Musa Cavendish* (Someya et al., 2002). However, no reports are available on the antioxidant properties of banana flour produced from *Musa* Awak.

The objective of this study was to determine the feasibility of using green banana flour as a source of fibre in noodles and to evaluate the effect of added oat β-glucan in noodles in terms of its chemical and sensory attributes. Besides, the effects of wheat flour substitution with green banana flour and oat β-glucan on phenols content, antioxidant properties (AP), carbohydrate digestibility and glycaemic indices of noodles will also be investigated.

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2. Materials and methods

2.1. Materials

Commercial noodle flour was obtained locally from the Malayan Flour Mills Company, Malaysia. Green banana (*Musa acuminata* × *balbisiana Colla* cv. *Awak)* was obtained from the local market in Penang. Oat β-glucan (NutrimO™) was purchased from Future Ceuticals, Midwest.

2.2. Green banana flour (*Musa acuminata* × *balbisiana Colla* cv. *Awak)* preparation

The sliced bananas were dried at 60 °C for 12 h, using a hot-air dryer (AFOS). The dried bananas were then ground and sieved into flour using a mill.

2.3. Noodle preparation

The flour mixture was blended in a mixer (Heavy Duty Kitchen Aid) with salt solution until it achieved the final optimum water absorption. The dough was then allowed to rest at room temperature (23 °C) for a further 15 min and then sheeted on a noodle machine (Ampia Model: 150, Marcato, Italy). The noodles were pre-cooked in boiling water for 1 min and rinsed with cool water.

2.4. Proximate analysis

Moisture, crude protein, ash, crude fat and crude fibre contents of noodles were determined according to a method of the AACC (2000). Protein content (%N × 5.7) was determined by the Kjeldahl method (AACC, Method 46-13). Moisture was determined by oven-drying for 4 h at 100–105 °C (AACC, Method 44-15A). Ash was measured by dry combustion (AACC, Method 08-01). Free lipids were measured by petroleum ether extraction, followed by evaporation to constant weight (AACC, Method 30-25). Dietary fibre was determined according to the procedure of AACC, Method 32-07. All sample measurements were done in triplicate.

2.5. Determination of essential mineral content

Essential mineral contents [phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca)] in samples were determined by using atomic absorption spectroscopy, AAS (Perkin Elmer 4100ZL). Absorbancies were recorded and a standard curve was plotted. Results were expressed as mg/100 g sample.

2.6. Total dietary fibre

Dietary fibre content was determined by an enzymatic–gravimetric method according the 16th Edition of the Official Methods of Analysis of the AOAC (1997), Method 985.29. Samples (dried and fat-free) were gelatinized with heat stable α-amylase and then enzymatically digested with protease and amyloglucosidase to remove the protein and starch present in the sample.

2.7. Resistant starch (RS)

Resistant starch content was determined according to Gõni, Garcia-Diz, Manas, and Saura-Calixto (1996). This method involved removal of protein with pepsin (40 °C, 1 h, pH 1.5), incubation with α-amylase (37 °C, 16 h) to hydrolyse digestible starch, treatment of the residues with 2 M KOH to solubilise RS and finally incubation with amyloglucosidase (60 °C, 45 min, pH 4.75) to hydrolyse RS. Free glucose was determined using the glucose oxidase assay GOD-PAP. RS was calculated as free glucose × 0.9 where 0.9 = correction factor (glucose–polysaccharide).

2.8. Determination of total starch

Total starch content was determined according to the method described by Goni, Garcia-Alonso, and Saura-Calixto (1997). (Factor conversion from glucose to starch was 0.9.)

2.9. In vitro starch digestibility

Carbohydrate digestibility of noodle was determined according to Wen, Lorenz, Martin, Stewart, and Sampson (1996). Salivary α-amylase (100 unit) was used for digestion. Absorbance was measured at 490 nm by using a UV-spectrophotometer. A calibration curve (0–200 μg) of maltose versus absorbance was made.

$$\text{Total carbohydrates digestion products} = \left(\frac{X \times \frac{100\ \text{ml}}{2\ \text{ml}} \times \frac{830\ \text{ml}}{2\ \text{ml}} \times 1\ \text{mg}/1000\ \mu\text{g}}{W}\right)\frac{1}{H}$$

where X = carbohydrates in 2 ml diluted dialysate by reference to the standard curve (μg), 100/2 = 2 ml from 100 ml diluted dialysate, 830/2 = 2 ml from 830 ml dialysate, W = weight of dry sample (g) and H = reaction time (h).

2.10. Estimated glycaemic index

In vitro kinetics of starch digestion were determined according to Goni et al. (1997). Glucose concentration was determined using a glucose oxidase–peroxidase kit (Sigma). The rate of starch digestion was expressed as a percentage of the total starch hydrolysed at different times (30, 60, 90, 120, 150 and 180 min).

The glycaemic indices of the samples were estimated according to the equation proposed by Goni et al. (1997). The area under the hydrolysis curve (AUC) was calculated using the equation: $\text{AUC} = C\infty(t_f - t_0) - (C\infty/k)[1 - \exp(t_f - t_0)]$, where C corresponds to the percentage of starch hydrolysed at time t, $C\infty$ is the equilibrium percentage of starch hydrolysed after 180 min, k is the kinetic constant and t is the time (min), t_f is the final time (180 min) and t_0 is the initial time (0 min). The hydrolysis index (HI) was obtained by dividing the area under the hydrolysis curve of each sample by the corresponding area of a reference sample (fresh white bread). The estimated glycaemic index (GI) was calculated using the equation: GI = 39.71 + (0.549 × HI).

2.11. Antioxidant properties (AP)

2.11.1. Preparation of noodle extracts for antioxidant studies

A pre-boiled noodle sample (100 g) was homogenised and mixed with 200 ml of methanol. The mixtures were stirred at room temperature for 60 min and filtrated through a Whatman No. 1 filter paper, followed by centrifugation at 3000*g* for 15 min. The supernatant was concentrated in a vacuum rotary evaporator at 50 °C. The concentrated solutions were freeze-dried and stored at −20 °C for further use.

2.11.2. Determination of antioxidant activity

The antioxidant activity of noodle extracts was determined according to the ferric thiocyanate method (Kikuzaki & Nakatani, 1993). The freeze-dried extracts (4 mg) were placed in a universal bottle containing 4 ml of ethanol (99.5%), 4.1 ml of 2.5% linoleic acid in 99.5% ethanol, 8 ml of 0.02 M phosphate buffer (pH 7) and 3.9 ml of distilled water. The mixture solution in the universal bottle was incubated at 40 °C. Every 24 h, 0.1 ml of sample was put into a test tube containing 9.7 ml of 75% ethanol and 0.1 ml of 30%

ammonium thiocyanate. The peroxide value was determined by reading the absorbance at 500 nm, 3 min after colour development with 0.1 ml $FeCl_2$. All test data are the average of triplicate analyses. The percentage of inhibition of peroxidation (%) was calculated as follows:

$$\text{Inhibition of peroxidation } (\%) = \left[\frac{1 - (\text{absorbance of sample at } 500\,\text{nm})}{(\text{absorbance of control at } 500\,\text{nm})}\right] \times 100$$

2.11.3. Determination of total phenolic (TP) compounds

Freeze-dried extracts (5 mg) of noodles were dissolved in 5 ml of DMSO. The resulting solution (0.5 ml) was added to 1 ml of 50% Folin–Ciocalteau reagent and incubated at room temperature. After 3 min of incubation, 3 ml of Na_2CO_3 (1%) was added to the mixture. The mixture was then left for a further 30 min. Absorbance was measured at 760 nm, using a spectrophotometer, with DMSO without freeze-dried extract as blank. Results were expressed as milligrams of gallic acid equivalents per 100 g of noodle extract (mg GAE/g extract). This reaction is sensitive to light; thus, test tubes used must be wrapped with aluminium foil and the absorbance was measured under dim conditions.

2.12. Sensory evaluation

Four types of noodle samples and the commercial sample (Soba Japanese noodle, CED®) were prepared for sensory evaluation. The samples were cut into 5 cm pieces and then boiled using tap water for the optimum cooking time. The samples were then stored for not more than one half hour in tightly covered plastic food containers before testing.

The sensory characteristics of the cooked noodles were evaluated by 20 panellists comprising students and staff of the Food Technology Division, Universiti Sains Malaysia. All samples, presented to each judge, were evaluated under red light using a nine point hedonic scale with "9" equalling "like extremely" and "1" equalling "dislike extremely". The attributes evaluated included colour, surface smoothness, firmness, elasticity, flavour and overall acceptability.

2.13. Statistical analysis

Data were analysed with SPSS version 110.0 (Illinois, U.S.A) using one-way analyses of variance (ANOVA). Significance was defined at $P < 0.05$ by using Duncan's test. At least three replications were made for chemical analysis and physical measurement.

3. Results and discussion

3.1. Chemical composition

The mean values for the proximate parameters, essential minerals, total starch and resistant starch (RS) of noodles are shown in Table 1. Moisture content of the noodles increased significantly ($p < 0.05$) with incorporation of 30% BF and also with addition of 10% oat bran to the noodles. This might have resulted from the addition of higher levels of water and increase in absorption rate during the mixing step. The optimum absorption of flour is influenced by starch damage and flour granulation (Oh, seib, Ward, & Deyoe, 1985).

Crude fibre content was significantly ($p < 0.05$) higher in 30% BF-substituted noodles (30BFG and 30BFN) than in the control. BF, produced from matured green banana was reported to be very rich in insoluble dietary fibre – hemicelluloses (6.08%, Mota, Lajolo, Ciacco, Cordenunsi, & Paulo, 2000). There was also an increment in crude fibre content with the addition of oat bran. This observation could have been attributed to the higher soluble fibre content contributed by the oat bran (5% per weight). However, percentages of crude fibre in the noodles were lower than in the TDF results (Fig. 1). This might be due to underestimation of dietary fibre in the samples, which resulted from solubilisation of hemicelluloses in sulphuric acid during the experiment.

There was a significant increment ($p < 0.05$) of crude protein content in noodle substituted with 30% BF (30BFG and 30BFN). However, this significant increment of protein was not contributed by the substituted BF since BF is low in protein content (3.8%, Kayisu, Hood, & Vansoest, 1981) compared to wheat flour (10–12%, Konik, Mikkelsen, Moss, & Gore, 1994). However, addition of gluten to the mixture could have caused the significant increment in crude protein content.

The ash contents in BF-substituted noodles (30BFG and 30BFN) were significantly ($p < 0.05$) higher than those of the control (conG and conN). The ash content depends on the quality of the flour (Kim, 1996) and thus corresponds to the higher mineral content (especially potassium) in BF which contributed to the significant higher ash content in BF noodles.

After addition of 10% oat β-glucan to noodles, the contents of crude protein, crude fat and ash were found to increase as compared to noodles without oat β-glucan. These results indicated that oat bran contributed certain amounts of protein, fibre and fat to the noodles.

Fat contents showed no significant difference ($p > 0.05$) among all samples and the fat contents in noodles without oat β-glucan (conG and 30BFG) were lower than those in the noodles with added oat β-glucan (conN and 30BFN). This was due to the lower fat content in BF (0.3–0.8%, Mota et al., 2000) compared to wheat flour (2%, Niihara, Yonezawa, & Matsuo, 1996). Moreover, fat content was decreased with formation of an amylose–lipid complex resulting from the heat treatment in BF production.

Among essential minerals, the most pronounced increment was observed in potassium and magnesium contents as 30% BF was added to the noodles. This is due to the high potassium (400 mg/100 g pulp) and magnesium (34 mg/100 g edible portion, McCance & Widdowson, 2002) contents in banana. Similar increments were observed for calcium and phosphorus content in BF-incorporated noodles (30BFG and 30BFN) compared with the control samples (conG and conN). This indicated that banana is a great source of magnesium, potassium, calcium and phosphorus.

The means of the mineral compositions of noodles containing oat β-glucan (conN and 30BFN) were higher than those of noodles without oat β-glucan (conG and 30BFG).

Significantly higher RS content was shown in noodle substituted with 30% BF and addition of 10% oat β-glucan. The higher content of RS in BF-substituted noodles was due to the higher starch content in the green banana (70–80% on dry weight basis, Zhang et al., 2005). Heat-moisture treatment is reported to help in generating RS type III (Lehmann, Jacobasch, & Schmiedl, 2002). Thus, the process involved in the production of BF, e.g., soaking and heating, helped the increased of RS content in BF. Moreover, native raw banana starch is known to be resistant to the attack of α-amylase and glucoamylase in the human digestion system. According to Zhang et al. (2005), almost 84% of starches escape digestion and reach the terminal human ileum.

Results also showed that the present of oat β-glucan significantly ($p < 0.05$) increased the RS content in noodles. This is because oat β-glucan helps in forming a viscous solution in the human digestion tract and retards the digestive enzyme activities.

For total starch analysis, results showed that total starch contents in 30BFG and 30BFN were significantly ($p < 0.05$) higher than in conG and conN. Higher total starch contents in BF-substituted noodles are contributed by the BF added. According to Zhang and

Table 1
Chemical compositions of different types of noodles.

	conG[b]	conN[b]	30BFG[b]	30BFN[b]
Moisture content (%)	33.40 ± 0.13	36.70 ± 0.37	39.19 ± 1.57	44.45 ± 0.13
Crude protein[a] (%)	9.80 ± 0.78	10.6 ± 0.02	11.8 ± 0.28	12.5 ± 0.04
Crude fibre[a] (%)	0.97 ± 0.36	2.16 ± 0.02	5.43 ± 0.67	6.91 ± 0.09
Crude fat[a] (%)	1.53 ± 0.07	1.70 ± 0.24	1.46 ± 0.02	1.61 ± 0.06
Ash[a] (%)	1.91 ± 0.14	1.93 ± 0.01	2.25 ± 0.07	2.33 ± 0.16
Phosphorus[a] (mg/100 g)	123 ± 2.40	127 ± 1.98	193 ± 1.90	202 ± 1.55
Magnesium[a] (mg/100 g)	27.2 ± 0.51	30.1 ± 1.12	60.4 ± 1.12	61.6 ± 1.01
Potassium[a] (mg/100 g)	265 ± 6.97	282 ± 2.47	360 ± 4.79	378 ± 5.58
Calcium[a] (mg/100 g)	53.1 ± 1.50	63.2 ± 1.29	83.1 ± 2.36	85.8 ± 2.92
Total starch[a] (%)	52.9 ± 1.32	59.8 ± 1.33	63.5 ± 1.02	68.3 ± 2.59
Resistant starch[a] (%)	3.68 ± 0.06	4.83 ± 0.01	12.3 ± 045	14.4 ± 0.31

[a] Expressed on a dry basis, and means ± standard deviation ($n = 3$).
[b] conG = control, conN = control + β-glucan, 30BFG = 30% BF, 30BFN = 30% BF + β-glucan.

Whistler (2002), matured green banana is known as a rich source of starch, which ranges from 70% to 80%. In contrast, the starch content in wheat flour is only 73% which is relatively lower than that of BF (Collado & Corke, 1996).

However, no significant difference was observed between noodle without oat β-glucan (conG and 30BFG) and noodles with added oat β-glucan (conN and 30BFN) in terms of total starch content. Oat β-glucan is a non-starch polysaccharide and thus did not show a significant effect on the amount of total starch in noodles.

3.2. TDF, IDF and SDF

Results of total dietary fibre (TDF), insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) are shown in Fig. 1.

BF-substituted noodles contained significantly more ($p < 0.05$) insoluble dietary fibre (IDF) than did the control samples (conG and conN). This observation was attributed to the high contents of hemicelluloses (type of IDF) present in BF (Mota et al., 2000). According to Southgate (1976) and VanSoest and Robertson (1977), banana pulp contained more hemicellulose than did most fruits and vegetables. However, no apparent increment of SDF content (average: 21.52%) was observed by adding 30% BF to noodles.

On the other hand, addition of 10% oat β-glucan to noodles significantly ($p < 0.05$) increased the SDF content (121%). Similar results were also obtained by Yokoyama et al. (1997), who reported that incorporated barley β-glucan in pasta significantly increased SDF content and resulted in a lower glycaemic response. Oat β-glucan is considered as fibre because it belongs to the soluble

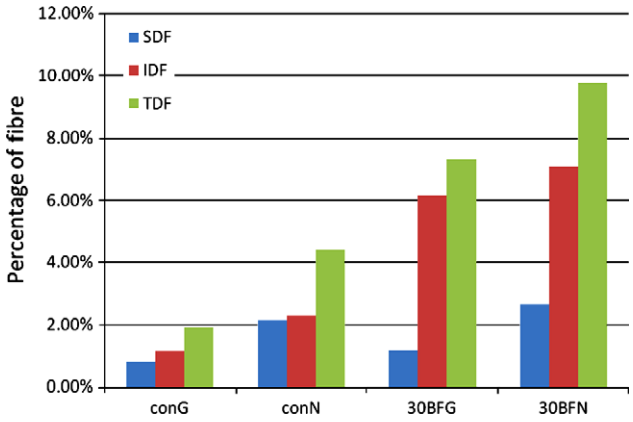

Fig. 1. Insoluble dietary fibre (IDF), soluble dietary fibre (SDF) and total dietary fibre (TDF) analyses for control (with and without oat β-glucan) and 30% BF-incorporated noodles (with and without oat β-glucan) (conG = control, conN = control + β-glucan, 30BFG = 30% BF, 30BFN = 30% BF + β-glucan).

hydrocolloids which are made up of glucosidyl units and are non-digestible in the human body due to the absence of an enzyme in the human intestine.

Due to the concomitant increases in IDF and SDF, results showed pronounced increment of TDF contents in noodles if 30% BF was added (Fig. 1). From this study, addition of 10% oat β-glucan significantly ($p < 0.05$) increased the TDF content. This increment was contributed by the significantly higher SDF in noodle with added oat β-glucan. According to Dougherty, Sombke, Irvine, and Rao (1988), TDF of pasta can be increased from 3% to 32.9% by adding 59% bleached oat fibre.

3.3. Carbohydrate digestibility

The carbohydrate digestibilities of noodles are given in Table 2. The total carbohydrate digestion products (TCDPs) were observed to increase with time. In the first hour of digestion, the level of TCDPs of noodles substituted with BF (30BFG and 30BFN) was significantly ($p < 0.05$) lower than that in the control (conG and conN). This is because 30BFG and 30BFN had greater protein and amylopectin contents which contributed to the more compact structures and made them less susceptible to amylase attack.

The restriction of enzyme hydrolysis is due to the strong bonding forces within starch granules and the high crystallinity degree of the banana starch granule. Moreover, banana starches appear to be highly resistant to enzymatic hydrolysis due to the presence of an external thick layer (7 μm) of larger blocklets (Gallent, Bouchet, Buleon, & Perez, 1992). According to Malleshi (2004), polyphenols will bind with amylases and slow down the carbohydrate digestibility of the sample. Consequently, it is believed that the higher contents of phenolic compounds in 30BFG and 30BFN than in the conG and conN caused the slower digestibility rate in BF-incorporated noodles.

The carbohydrate digestibilities of noodles mixed with oat β-glucan (conN and 30BFN) are significantly ($p < 0.05$) different from those of noodles without β-glucan (conG and 30BFG). This is because β-glucans with (1 → 3) linear bonds were hydrolysed and increased the TCDP in β-glucan-added noodles.

3.4. Estimated glycaemic index (GI)

The estimated glycaemic indices, GI for four different types of noodles are shown in Table 2 and Fig. 2 shows the starch hydrolysis curves. GI is used as an indication of postprandial blood glucose and insulin response. GI for the four types of noodles ranged between 30 and 52. The lowest GI was estimated for 30BFN, followed by conN and 30BFG, and conG shows the highest GI. However, the GI for these four different types of noodles are low (<55) and were classified as low GI food (McCord, 2006). In this study, the GI val-

Table 2
Carbohydrate digestibilities and glycaemic indices of different types of noodles.

	Total carbohydrate digestibility products[a], TCDPs (mg/g/h)			Glycaemic index[a] (GI)
	1 h	2 h	3 h	
conG[b]	7.14 ± 0.18	13.1 ± 1.27	37.6 ± 1.17	52.9 ± 0.52
conN[b]	11.0 ± 0.56	21.9 ± 1.80	39.5 ± 0.55	35.3 ± 0.26
30BFG[b]	9.01 ± 1.35	15.5 ± 0.42	38.4 ± 0.47	39.7 ± 1.65
30BFN[b]	10.6 ± 0.37	18.4 ± 1.36	49.2 ± 1.85	31.0 ± 1.01

[a] Values are expressed in means ± standard deviation (n = 3).
[b] conG = control, conN = control + β-glucan, 30BFG = 30% BF, 30BFN = 30% BF + β-glucan.

ues of 30BFG and 30BFN are found to be as low as in spaghetti (GI: 41) and Fettuccine (GI: 32), respectively.

The lowest GI of 30BFN is in line with the oat β-glucan added and with the highest dietary fibre contents, especially soluble fibre in the noodle (Fig. 1). This indicated that addition of 10% of β-glucan can significantly reduce the GI of food and this effect is greater than that in wheat flour just substituted with BF in noodles. According to Kabir et al. (2002), intake of low GI breakfast which contains 3 g of β-glucan for 4 weeks lowers and controls postprandial glycaemic responses.

The reduced insulin responses in noodles treated with β-glucan (conN and 30BFN) are attributed to the decrease in the rate of postprandial glucose absorption. Oat β-glucan belongs to a type of soluble fibre which swells and gradually dissolves in water and forms pseudoplastic viscous solutions. The viscous solution may reduce activities of gastrointestinal enzymes, including amylase, lipase and chymotrypsin, towards their substrates and also retard absorption of nutrients which include plasma glucose (Lund, Gee, Brown, Wood, & Johnson, 1989). Compared with soluble fibre, insoluble fibre showed less effect in reducing the glycaemic response.

On the other hand, a lower GI is observed in noodles incorporated with 30% BF compared to the control samples. This reduction of GI corresponds to the lower rate of starch hydrolysis in BF-incorporated noodles. Fig. 2 indicates that 30BFG and 30BFN are lower in starch hydrolysis rate than are the controls (conG and conN). This is due to the degree of crystallinity that substantially affects starch digestibility. Instead of amylose, retrogradation of amylopectin, which forms a more complex structure, caused the slowdown of starch hydrolysis. Therefore, crystalline structures of banana starches are hardly accessible by the enzyme and are thus resistant to *in vivo* amylase hydrolysis. The rate of starch hydrolysis and postprandial plasma glucose or insulin levels were shown to be low. The reduced insulin response might be attributed to the delay in glucose absorption and this improved the metabolic control which is important in diabetic patients.

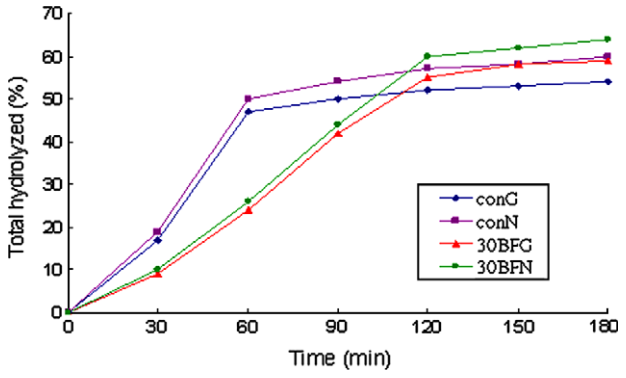

Fig. 2. *In vitro* starch hydrolysis rates of four different types of noodles (conG = control, conN = control + β-glucan, 30BFG = 30% BF, 30BFN = 30% BF + β-glucan).

3.5. Total phenols (TP) and antioxidant properties (AP)

The results of phenol analysis and antioxidant activity are given in Table 3. TP contents differ significantly ($p < 0.05$) among samples. The 30BFN noodle TP was significantly higher than those in the other samples. The higher TP content in the noodle was contributed by the BF which contains more phenolics. In contrast, green banana is abundant in TP content (232 mg/100 g pulp, Someya et al., 2002) and contains various flavonoids, especially catechin, epicatechin, gallocatechin, dopamine and tannin. Among the antioxidant compounds, gallocatechin (Someya et al., 2002) and dopamine are most abundant in green banana pulp.

As shown in Table 3, TP content is higher in conN than in conG and higher in 30BFN than in 30BFG. This observation indicates that addition of 10% oat β-glucan resulted in significant increase ($p < 0.05$) in TP content of noodle. According to White and Xing (1997), oat bran exerted a moderate antioxidative activity and ferulic acid is the most abundant phenolic compound formed in oat flour. The outer layers of grain have greater concentrations of TP than have extracts from other milling fractions. Thus, oat β-glucan extracted from oat bran has a greater concentration of TP and consequently increases the amount of TP in noodles.

High inhibition of linoleic acid peroxidation indicates a high antioxidant activity. Noodle 30BFN, which exhibited the highest inhibition, was significantly ($p < 0.05$) higher than were conG and conN but not different from ($p > 0.05$) 30BFG (Table 3). The significantly higher antioxidative activity in BF-incorporated noodles was attributed by the higher content of the TP and the strong antioxidative ability of phenolic compounds present in BF. Inhibition of linoleic peroxidation in noodles was also increased by addition of 10% oat β-glucan. However, the antioxidative ability is not as great as in BF. This is because oat (caffeic and ferulic acids) has only a weak antioxidative activity (Osawa, Ide, Su, & Namiki, 1987) compared to banana.

3.6. Sensory evaluation

Sensory evaluation (Fig. 3) indicated that the firmness of the 30BFG was significantly highest ($p < 0.05$) (score = 6.28) among all samples. However, the commercial noodle showed the lowest score (4.50) in firmness. This might be due to the low gluten content in the soba type of noodle. Results also showed no significant difference ($p > 0.05$) in elasticity among all samples, with the exception of the commercial noodle. Panellists found that commercial noodle was moderately resilient while other samples were slightly elastic. ConG scored the highest in terms of surface smoothness (6.56 ± 0.46) while no significant difference ($p > 0.05$) was observed in other samples which ranged from 4.92 to 5.56. The commercial noodles which scored the highest (7.06 ± 1.01) for colour measurement were described as being darker in colour. However, conG was rated as the brightest in colour (score = 2.83).

Table 3
Antioxidant activities and total phenolic contents of different types of noodles.

	Total phenolic content[a] (mg GAE/100 g extract)	Inhibition of peroxidation[a] (%)
conG[b]	28.6 ± 0.84	17.7 ± 0.91
conN[b]	44.9 ± 0.14	36.6 ± 0.67
30BFG[b]	90.4 ± 2.20	52.7 ± 0.64
30BFN[b]	123 ± 2.24	60.4 ± 1.11

[a] Values expressed are in means ± standard deviation ($n = 3$).
[b] conG = control, conN = control + β-glucan, 30BFG = 30% BF, 30BFN = 30% BF + β-glucan.

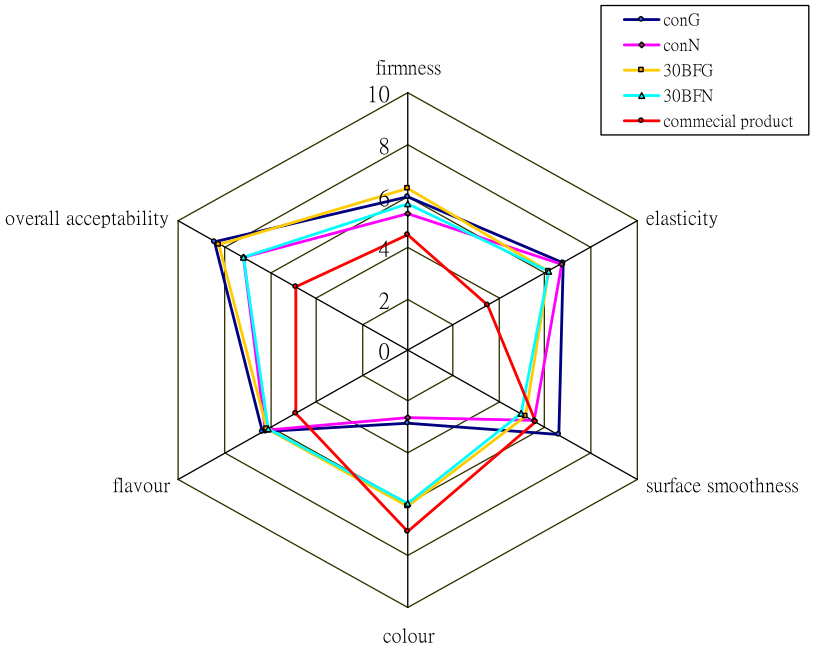

Fig. 3. Sensory analyses of four different types of noodles (conG = control, conN = control + β-glucan, 30BFG = 30% BF, 30BFN = 30% BF + β-glucan).

Except for the commercial noodles, the scores for flavour were in the range of "like slightly" and not significantly ($p > 0.05$) different among the samples. Thus, sensory panels exhibited preferences for the flavours of BF-incorporated noodles (30BFG and 30BFN) since the results are not significantly different from the control sample (conG). Therefore, incorporation, up to 30%, of BF in the formulation does not affect the flavour of noodle products.

Overall, conG and 30BFG were similar in overall acceptability, even though the conG scored the highest acceptability. However, results also showed that addition of oat β-glucan affected the overall acceptability of noodles due to the relatively lower firmness, elasticity, surface smoothness and flavour scores obtained for noodles with added oat β-glucan (conN and 30BFN) compared to noodles without oat β-glucan (conG and 30BFN).

4. Conclusion

Green banana flour (BF), produced from *Musa Awak*, has potential as source of fibre when substituted in noodle products. The incorporation of 30% BF significantly increased the total dietary fibre of noodle, resistant starch, total starch and some essential minerals, including phosphorus, magnesium, potassium and calcium. Besides, substitution of 30% BF in noodle increased the moisture, crude protein, crude fibre, and ash contents. Therefore, this produced a good quality noodle in terms of nutritional values and sensory acceptability.

Noodles substituted with 30% BF showed lower carbohydrate digestibility rate than did the control and had a lower GI. However, compared to the noodle with substituted 30% BF and added oat β-glucan, it showed greater effect in retarding the rate of carbohydrate digestibility and reducing the GI of noodles. Addition of 10% oat β-glucan resulted in a pronounced increment of soluble fibre content and significantly reduced the GI of noodles. Oat β-glucan also contributed certain amounts of protein, crude fibre, crude fat, ash, amylose and total starch to noodles.

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