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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%