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Effect on Nutritional and Antioxidant Properties of Yellow Noodles Substituted with Different Levels of Mangosteen (*Garcinia mangostana*) Pericarp Powder

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Abstract**—**Mangosteen (*Garcinia mangostana*) pericarp is considered as agricultural waste and not fully utilized in food products. It is widely reported that mangosteen pericarp contains high antioxidant properties. The objective of this study is to develop novel yellow alkaline noodle (YAN) substituted with different levels of mangosteen pericarp powder (MPP). YAN formulation was substituted with different levels of MPP (0%, 5%, 10% and 15%). The effect on nutritional and antioxidant properties was evaluated. Higher substitution levels of MPP resulted in significant increase ($p<0.05$) of ash, fibre, specific mineral elements and antioxidant properties (total phenolic, total flavonoid, anthocyanin and DPPH) than control sample.

Keywords**—**Yellow alkaline noodle, mangosteen pericarp powder, proximate composition, antioxidant properties.

I. Introduction

MANGOSTEEN pericarp (*Garcinia mangostana* L.) is known as "queen of the fruit" largely planted in Southeast Asia, particularly in Malaysia, Thailand, and Indonesia. Mangosteens are small (about 4 to 8 cm in diameter) round fruits with thick, brittle, deep purple spherical outer pericarp [1]. They have been reported to contain medicinal and health promoting properties. In Malaysia, mangosteen pericarp is considered as agricultural waste during its season although the pericarp is rich with bioactive compounds with potential applications as therapeutic agents or as a nutraceutical [2], [3].

Antioxidant is a substance that prevents oxidation of important biomolecules. They scavenge radicals by inhibiting initiation and breaking chain propagation or suppressing formation of free radicals by binding to the metal ions, reducing hydrogen peroxide, and quenching superoxide and singlet oxygen. Fruits which contain highest radical scavenging activities tend to have high level of phenolic content [4]. Mangosteen has been reported to contain an abundant source of polyphenols known as xanthones. Several xanthones have been isolated from mangosteen pericarp are α-mangostin, β-mangostin, γ-mangostin, gartanin, mangostanin and 8-deoxygartanin. Its pericarp also contains flavonoids (epicatechin) and anthocyanins [3]. The activities of xanthones that are isolated from pericarp of mangosteen are antioxidant, antitumoral, anti-inflammatory, anti-allergy, anti-bacterial, antifungal and anti-viral. People have been using dried pericarp as a traditional medicine for the treatment of abdominal pain, diarrhea, dysentery, infected wound, suppuration and chronic ulcer [5].

Dietary fibre demonstrated beneficial effects in protection against heart disease and cancer, normalization of blood lipids, regulation of glucose absorption and insulin secretion and prevention of constipation and diverticular disease [6]. Some studies demonstrated that consumption of dietary fibre and phenols from fruits and vegetables improved lipid metabolism and prevent the oxidation of low density lipoprotein cholesterol (LDL-C), which subsequently will hinder the development of atherosclerosis [7]. Mangosteen pericarp powder contains high dietary fibre content (10.6g/100g) (data not shown), which has the potential to be an alternative local source of dietary fibre.

The essential minerals are divided into two subgroups i.e. major minerals and trace minerals, based on their dietary requirement. Most essential minerals primarily serve as structural and functional components of body tissues. However, most of the essential minerals are not stored by the body and thus required daily supplementation in the diet [8]. Mangosteen contains minerals such as potassium, magnesium, iron, and zinc.

Yellow alkaline noodles (YAN) are an important part of Asian cuisine and economically significant. Approximately 40% of the total wheat flour consumption is in the form of noodles in Asia. It is widely consumed in Southeast Asia, Southern China and Japan. The most common ingredients to produce yellow alkaline noodles are wheat flour, water, alkaline salts (primarily sodium and potassium carbonate or known as *kansui*) and sodium chloride (salt) [9]. Commercialized yellow alkaline noodles are rich in carbohydrate, but deficient in essential nutrients such as dietary fibre, minerals, vitamins, antioxidants and proteins. Several attempts have been carried out to enhance the quality of yellow alkaline noodles with non-wheat flour such as hull-less barley flour [10], matured banana flour and β-glucan [11], and sweet potato and soy flour [12].

Addition of non-wheat flour containing natural antioxidants, dietary fibre and minerals in food products such as noodles, pasta, and bread products represent as the alternative technique to enhance the quality and nutritional value of food products. However, only few studies concerning

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the dietary fibre, minerals content and the addition of antioxidants in yellow alkaline noodles are available. Mangosteen pericarp is not fully exploited in food products although it contains high nutritional properties i.e. antioxidants, dietary fibre and minerals.

Hence, the objectives of this study are to develop novel yellow alkaline noodles with different substitution levels of mangosteen pericarp powder (0%, 5%, 10% and 15%) to enhance its nutritional properties. The nutritional and antioxidant properties of yellow alkaline noodles substituted with different levels of mangosteen pericarp powder were evaluated through this study.

II. Materials and Methods

Mangosteen pericarp was collected from local farm in Kuala Kangsar, Perak, Malaysia. The ingredients for yellow alkaline noodles were purchased from local store in Shah Alam, Selangor, Malaysia.

A. Preparation of Mangosteen Pericarp Powder

Mangosteen (*Garcinia mangostana*) with maturity index of 6 (brownish purple) to 7 (dark colour) pericarp was washed under running tap water to remove any foreign material. The pericarp was cut into small pieces and air-dried at 60^oC for 24 hours. Dried mangosteen pericarp was ground by using Waring blender to pass through US70 (212 µm dia.) and stored in an airtight opaque container at $\leq 5^oC$ prior to use.

B. Preparation of Yellow Alkaline Noodles

The preparation of yellow alkaline noodles was described by [13]. Flour was mixed with 1% NaCl and 2% *kansui* solution until it achieved optimum water absorption. The dough was allowed to rest at room temperature for 30 minutes followed by sheeting and cutting process using pasta machine. The noodles were pre-cooked in boiling water for 1 minute in a ratio of 1:10 of noodles to flour and rinsed with cool water [13]. Mangosteen pericarp powder (MPP) was substituted with wheat flour at four different levels (0%, 5%, 10%, 15% w/w).

C. Proximate Composition

Yellow alkaline noodle samples were analysed for moisture (Method 44-15A), crude protein (*N* x 6.25) (Method 46-13), crude fibre (Method 32-10), crude fat (Method 30-25) and ash (Method 08-01) content according to AACC (2000) [14]. Carbohydrate content was determined by difference:

$$[100 – (\text{moisture} + \text{crude protein} + \text{crude fibre} + \text{crude fat} + \text{ash})] \quad (1)$$

Calorie value of bread samples was calculated according to (2):

$$\text{Calorie value (kcal/100g)} = (\%\ \text{crude protein} \times 4) + (\%\ \text{carbohydrate} \times 4) + (\%\ \text{fat} \times 9) \quad (2)$$

All analyses were performed in triplicates.

D. Specific Mineral Analysis

Specific mineral elements analysis (Fe, Zn, Ca, Mg, K) was analyzed according to the Method AOAC 2011.19 [15]. Samples were digested and the resultant mixture was filtered with 20 - 25µm diameter pore filter (Whatman) and diluted to 50 mL with deionized water. Specific mineral element was measured by using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (Perkin-Elmer 5300 DV). The analysis was carried out in triplicates.

E. Determination of Total Phenolic Content (TPC)

Total phenolic content was determined by using Folin-Ciocalteu reagent [16]. Approximately, 5 g of sample was extracted with 50 ml of acetone-water mixture (1:1 v/v) for 15hrs at room temperature. After filtration, the acetone extracts were kept in the dark at room temperature until further analysis. The reaction mixture contained 50 ml of sample extracts, 250 ml of Folin-Ciocalteau reagent, 0.75 ml of sodium carbonate (20 g/100 ml) and 3 ml of deionized water. After 2 hrs of reaction at ambient temperature, the absorbance of sample was measured at 725nm using a spectrophotometer. The phenolic content was calculated by using gallic acid as a standard. The results are expressed as mg gallic acid equiavalent per gram of sample (dry weight). Analysis was carried out in triplicates.

F. Determination of Free Radical Scavenging Activity (DPPH)

Free radical scavenging activity was determined according to the method of [17]. In brief, 2 ml of 0.16 mM DPPH solution (in methanol) was added to the test tube containing 2 ml sample extract (1 mg/ml distilled water). The mixture was vortexed for 1 min and left to stand at room temperature for 30 min in the dark. The absobance of resulting solution was measured at 517 nm by using spectrophotometer. Sample blank and control samples were performed according to the method. The scavenging effect (%) was calculated by using:

$$\text{Scavenging effect (\%)} = 1 – \left(\frac{\text{Absorbance of sample at 517 nm}}{\text{Absorbance of control at 517 nm}}\right) \times 100 \quad (3)$$

G. Determination of Total Flavonoid Content (TFC)

Total flavonoid content was determined according to [18]. Extracted sample in 0.5 mL with 2.25 mL distilled water was added in a test tube together with 0.15 mL of 5% sodium nitrite. After 6 minutes, 0.3 mL of 10% AlCl3.6H2O was added and allowed to stand in room temperature for 5 minutes followed by addition of 1 mL of 1M NaOH. The absorbance of sample and standard (quercetin) was read immediately at 510 nm using spectrophotometer. Each formulation was analyzed in triplicates and calculated as mg quercetin equivalents in 1 g sample (mg QE/g dry weight).

H. Determination of Anthocyanin Content (AC)

Anthocyanin content was conducted according to pH differential method. Potassium chloride (KCl) buffer, 0.025 M, pH 1.0 was made by mixing 1.86 g of KCl and 980 mL of distilled water in a beaker. Concentrated HCl was used to adjust the pH and transferred to a 1 L volumetric flask with distilled water.

Anthocyanin analysis was prepared from two dilutions, one with potassium chloride buffer, pH 1.0, and the other with sodium acetate buffer, pH 4.5. Extracted sample (1 mL) was added into volumetric flask and adjusted with buffer. Then, the solution was diluted and equilibrates for 15 minutes. Absorbance of sample was read at 510 nm and 700 nm by using spectrophotometer. Anthocyanin content was expressed as cyanidin-3-glucoside and calculated as:

$$\text{Monomeric anthocyanin pigment (mg/L)} = \frac{(A \times MW \times DF \times 1000)}{(\varepsilon \times 1)} \quad (4)$$

MW is the molecular weight of cyanidin-3-glucoside, DF is the dilution factor, and ε is the molar absorptivity.

I. Statistical Analysis

Statistical analysis of the result was analysed by using analysis of variance (ANOVA) and significant differences among means of triplicate analysis at ($p<0.05$) was determined by Duncan's multiple range test.

III. Results and Discussions

A. Proximate Analysis

The result of main constituents in sample of yellow alkaline noodles (YAN) substituted with different levels of mangosteen pericarp powder (MPP) is presented in Table I.

The result shows that the moisture and protein content of YAN are significantly decreased ($p<0.05$) with higher substitution level of MPP in YAN formulation. Moisture content of YAN with elevated amount of MPP decreased significantly due to the presence of dietary fibre in MPP absorbed more water. In production of YAN, high or medium strength of wheat flour (protein content in the range of 10 – 12.5%) is commonly used [19]. Gluten is the major component in the dough that responsible for the gluten network development. However, MPP is having very low amount of protein content (0.38 g/100g) (data not shown). Thus, at higher MPP substitution level, the protein content in YAN decreased, and subsequently reduced the gluten in the formulation.

From Table I, the value of ash, crude fibre and crude fat content of YAN were increased significantly ($p<0.05$) with the increased substitution level of MPP in the formulation. Significant increase in ash and crude fibre content was attributed by high ash (3.38 g/100 g) and crude fibre (10.60 g /100 g) in MPP than commercial wheat flour. Ash content is the approximate indicator of the total content of mineral elements in foodstuffs. Dietary fibre in MPP modified the water absorption of the dough as the fibre is very hydrophilic which absorbed almost its weight of water [20]. According to [21], some of the total content of antioxidant polyphenols and carotenoids in fruit and vegetables are bound to the dietary fibre matrix. Hence, a significant proportion of the total antioxidant capacity in fruit and vegetables is associated with DF content.

B. Specific Mineral Elements

The major essential mineral elements analyzed were potassium, calcium, and magnesium while the trace minerals are zinc and iron. Some mineral elements found in mangosteen are calcium (18mg/100g), iron (0.3mg/100g), magnesium (13mg/100g), potassium (48mg/100g), and zinc (0.21mg/100g) [22]. Specific mineral elements of YAN with different substitution levels of MPP are summarized in Table II.

All major mineral elements analyzed were found to significant increased ($p<0.05$) as the MPP substitution level increased in YAN formulation. Potassium and calcium content increased by 2-fold and 1.3-fold, respectively in YAN with 15% MPP than control sample. These macro minerals are closely related to each other, as their consumption is vital in maintaining the regulations of cells and other nutrients in the body. Meanwhile, the amount of trace minerals of YAN resulted in significant increase ($p<0.05$) for iron and zinc content with the increased substitution level of MPP in the formulation. Addition of 15% defatted wheat germ flour (DWGF) in YAN resulted in better major and trace mineral elements than other noodle samples [23]. Substitution of MPP into YAN formulation is a strategy to improve the essential mineral elements that are deficient in the wheat flour.

C. Antioxidant Properties

Mangosteen pericarp has been widely reported as having high antioxidant activities. Antioxidant properties of yellow alkaline noodles (YAN) substituted with different levels of MPP is shown in Table III. From the result, total phenolic, total flavonoid, total anthocyanin content and free radical scavenging effect (DPPH) showed significant increased ($p<0.05$) at higher MPP substitution level in YAN samples.

Total phenolic content of YAN with 15% MPP increased significantly ($p<0.05$) by 7-fold than in control sample. Higher phenolic content with increased substitution level of MPP in YAN formulation attributed to various active components such as tannins, saponins, and polyphenolics [24]. Mangosteen pericarp was reported to contain high phenolic content such as procyanidin, prodelphinidin, sterioisomers of afzekechin/epiafzelechin, catechin/epicatechin, and gallocatechin/epigallocatechin [25] which contributed to the elevated amount of phenolic content with higher MPP substitution level in YAN. Study conducted by [26] reported significant higher ($p<0.05$) antioxidative activity in YAN substituted with matured banana flour due to the higher content of total phenols and strong antioxidative ability of phenolic compounds present in matured banana flour. Pasta with incorporation of sorghum flour and common bean flour resulted with higher total phenolic content than control pasta [27], [28].

TABLE I
PROXIMATE COMPOSITION OF YELLOW ALKALINE NOODLES SUBSTITUTED WITH DIFFERENT LEVELS OF MANGOSTEEN PERICARP POWDER (MPP)

Composition (g/100g)	Control	5% MPP	10% MPP	15% MPP
Moisture	62.53±0.06^{d}	58.78±0.07^{b}	55.92±0.03^{c}	53.76±0.05^{d}
Fat	3.55±0.01^{c}	3.57±0.013^{c}	3.64±0.01^{b}	3.79±0.02^{d}
Protein	4.47±0.12^{a}	3.74±0.09^{b}	3.65±0.05^{b}	2.63±0.08^{c}
Ash	1.72±0.01^{d}	1.85±0.01^{c}	1.96±0.03^{b}	2.01±0.01^{a}
Crude fibre	0.70±0.02^{d}	1.45±0.04^{c}	1.81±0.01^{b}	1.97±0.01^{a}
Carbohydrate	27.02±0.08^{a}	30.60±0.14^{c}	33.02±0.05^{b}	35.84±0.06^{a}
Calorie (kcal/100g)	157.94±0.29^{d}	169.55±0.30^{c}	179.43±0.23^{b}	187.99±0.23^{a}

MPP: Mangosteen Pericarp Powder. Values are expressed as mean±s.d. *n=3*.Means with different letters in the same row are significantly different (p<0.05).

TABLE II
MINERAL ELEMENTS OF YELLOW ALKALINE NOODLES SUBSTITUTED WITH DIFFERENT LEVELS OF MANGOSTEEN PERICARP POWDER (MPP)

Element (mg/g)	Control	5% MPP	10% MPP	15% MPP
Iron	0.23±0.01^{b}	0.24±0.00^{a}	0.25±0.00^{a}	0.25±0.00^{a}
Zinc	0.02±0.00^{b}	0.02±0.00^{b}	0.03±0.00^{a}	0.03±0.00^{a}
Calcium	0.83±0.01^{c}	0.87±0.00^{c}	0.97±0.06^{b}	1.09±0.06^{a}
Magnesium	0.44±0.00^{c}	0.44±0.00^{c}	0.45±0.00^{b}	0.49±0.00^{a}
Potassium	0.76±0.01^{d}	1.03±0.03^{c}	1.30±0.05^{b}	1.64±0.04^{a}

MPP: Mangosteen Pericarp Powder. Values are expressed as mean±s.d. *n=3*.Means with different letters in the same row are significantly different (p<0.05).

TABLE III
ANTIOXIDANT PROPERTIES OF YELLOW ALKALINE NOODLES SUBSTITUTED WITH DIFFERENT LEVELS OF MANGOSTEEN PERICARP POWDER (MPP)

Antioxidant properties	Control	5% MPP	10% MPP	15% MPP
Total Phenolic Content (mg GAE/g)	1.22±0.21^{c}	5.40±0.15^{b}	5.80±0.15^{b}	8.83±0.35^{a}
Total Flavonoid Content (mg QE/g)	0.66±0.12^{c}	2.58±0.55^{b}	3.18±0.22^{b}	4.02±0.15^{d}
Anthocyanin Content (cyanidine-3-glucosid equiv., mg/L)	5.68±3.29^{b}	20.45±0.63^{a}	21.99±0.98^{a}	25.16±2.93^{a}
DPPH (% scavenging activity)	20.2±0.85^{d}	42.5±0.50^{c}	67.3±0.25^{b}	82.7±0.35^{a}

MPP: Mangsteen Pericarp Powder. Values are expressed as mean±s.d. *n=3*. Means with different letters in the same row are significantly different (p<0.05).

Total flavonoid content increased significantly (p<0.05) at higher substitution level of MPP in YAN. YAN substituted at 15% MPP resulted with the highest total flavonoid content. However, the value of flavonoid content in the samples is considered as low due to the pre-cook process and samples were extracted with ethanol which gives lower flavonoid levels [29].

Anthocyanin content and free radical scavenging effect (DPPH) increased significantly (p<0.05) by 4-fold in YAN with 15% MPP substitution level. The major anthocyanin found in mangosteen pericarp is cyanidin-3-sophoroside [30]. Both total phenolic and anthocyanin content were positively related with free radical scavenging effect. The value of DPPH in YAN with 15% MPP (82.7%) may be suggested that MPP may act as free radical scavenger and may react with radicals to convert them to more stable products and terminate radical chain reaction [31]. Basically, a higher value of DPPH radical scavenging activity is associated with lower value of IC_{50} (concentration necessary to inhibit 50% of DPPH radical absorbance) [32]. Study conducted by [33] reported significant increase (p<0.05) of DPPH values in spaghetti substituted with 15% carrot pomace flour compared to control. Mangosteen pericarp was reported containing IC_{50} values comparable to BHT [25]. This shows that substitution of MPP contributes higher antioxidant activity in YAN formulation. Hence, MPP is a good source of antioxidants to be added into YAN to further enhance their nutritional content.

IV. CONCLUSIONS

In conclusion, mangosteen pericarp powder (MPP) is a good source of dietary fibre, minerals and antioxidants to improve and enhance the nutritional content of food products. With higher substitution level of MPP in YAN formulation, resulted in an improved nutritional quality such as fibre, ash, and specific mineral elements. Antioxidant properties i.e. total phenolic, total flavonoid, anthocyanin and DPPH of YAN showed significant increase at higher MPP substitution level. However, the moisture and protein content of YAN decreased as the substitution level of MPP increased in the formulation. Hence, MPP has a great potential to be further utilized by incorporating into food products so as to enhance the nutritional value particularly dietary fibre, minerals and antioxidant properties.

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