Effect of watermelon rind powder on physicochemical, textural, and sensory properties of wet yellow noodles

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Introduction

Noodles have been considered as a secondary staple food for human and remain an important part of the diet in many Asian countries. The popularity of noodles has been increasing worldwide because of their affordable prices, palatable taste, and cooking convenience. Therefore, the noodle-related industry has experienced consistent growth over the last several years. Noodle is a major carbohydrate-based food and is a main source of wheat products in the Asian diet (Jang, Bae, & Lee, 2015). According to Ma et al. (2014), noodles occupy nearly 40% of the total wheat flour consumption in several Asian countries. Noodles are made from wheat flour, water, sodium chloride, and kansui reagent or alkaline salt solution. The alkaline salts are usually sodium or potassium carbonates, exhibiting a diversity of ratios and dosages (Hatcher & Anderson, 2007).

In recent years, the demand for wheat-based products with added value or functional (higher amounts of dietary fiber and antioxidants) is growing rapidly in accordance with an increasing number of people aware about the consumption of healthier food in their daily diet (Singh, Kaur, Shevkani, & Singh, 2015). Noodles are made from wheat flour, which is a rich source of carbohydrate, but lacks many other essential components (such as minerals and dietary fiber), which are lost during the wheat flour refinement process (Choo & Abdul Aziz, 2010). Hence, the large-scale consumption of wheat-based products could lead to malnutrition. Therefore, to meet the sufficient intake of dietary fiber in human daily diet, the innovation of enriched wheat-based products such as noodles enriched or fortified with mineral and dietary fiber is necessary to be developed. Several studies have been carried out on the partial replacement of wheat flour with natural fiber ingredients such as banana flour, kenaf seeds flour, cassava pulp, pomelo peel, and sweet potato flour (Choo & Abdul Aziz, 2010; Ginting & Yulifianti, 2015; Wandeel et al., 2014; Zawawi et al., 2014) for composite noodles preparation.

Agricultural and industrial by-products are attractive sources of dietary fibers and minerals, which have the potential to compensate the deficiency of these nutrients in noodles. Watermelon, belonging to the family Cucurbitaceae, is rich in dietary fiber and minerals, and it can be used as a natural fiber source in the enrichment process of noodle.
one of the major underutilized fruits grown in the warmer parts of the world (Dane & Liu, 2007). The pulp and juice of watermelon are used for human consumption, while the rind and seeds, representing 30% of the whole fruit, are the major solid wastes (Anonymous, 2014). Recent research shows that the watermelon by-products are important sources of protein, dietary fibers, and natural antioxidants (Al-Sayed & Ahmed, 2013) especially of pectin, cellulose, citrulline, and other phytochemical compounds (Johnson et al., 2012; Rimando & Perkins-Veazie, 2005). In addition, Oseni and Okoye (2013) showed the rind of the watermelon possesses a good amount of total phenol contents (0.248 mg/ml) and high free radical scavenging ability (hydroxyl radical scavenger).

Water is the most important factor to accelerate the food deterioration process and microbial spoilage (Sewald & De Vries, 2015). Bad handling of watermelon by-products after fruit processing causes the fresh watermelon rind to deteriorate and results in large physical damage and loss in a short period of time. Hence, processing of watermelon into powder by reducing the water content is needed for extension of shelf life. Watermelon rind powder (WRP) could be a potential source of fiber in foods, especially wet yellow noodles. Application of WRP in noodle has hitherto not been investigated. Hence, the present study aimed to develop new composite noodles incorporated with WRP at levels of 50, 100, and 150 g/kg (based on a flour basis). In addition, the effects of WRP incorporation on the qualities of noodles, including proximate composition, total phenolic content (TPC), color, textural properties, pH value, cooking quality, and sensory quality, were investigated.

Material and methods

WRP preparation

Watermelon (Citrullus lanatus) rind (white part) was separated from washed fresh fruits manually with a sterile knife. The rind was cut into small pieces, sliced using the slicer before drying in a ventilated dryer at 50°C for 24 h. The dried slices of watermelon rind were then ground in a laboratory mill and further sieved through a 250-μm mesh sieve to fine powder and kept in an airtight plastic container and stored in a chiller prior to use.

Wet yellow noodle preparation

Noodles were prepared using the method described by Saifullah, Abbass, Yeo, and Azhar (2009), with some modifications. WRP replaced the wheat flour at the levels of 50, 100, and 150 g/kg for the preparation of WRP5, WRP10, and WRP15, respectively. Noodle formulated without WRP was used as the control (WRP0). The noodle formulation consisted of 100 g of mixed flour (wheat flour and WRP), 34 ml water, 2 g sodium chloride, and 1 ml kansui reagent or alkaline salt (active ingredients: sodium silicate and sodium carbonate). Kansui reagent was added into the formulation to inhibit enzyme activity and minimize enzymatic darkening. It is also a vital ingredient in improving the flavor and texture of the noodles. Wheat flour was initially mixed with WRP using a mixer (KitchenAid, USA) for 2 min. Pre-dissolved salt and kansui reagent were then added to the mixing bowl. The suspension was mixed at speed 1 (60 rpm) at room temperature for 10 min to form a smooth dough. Dough was then allowed to rest for 20 min before being sheeted on a noodle machine (Nanjing Hope, HP-150, Jiangsu, China) to obtain the desired thickness.

Proximate analysis

The proximate contents of the samples were determined according to the official method as described by AOAC (1995). 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) were applied to analyses moisture, crude protein, crude fat, ash, and crude fiber, respectively. Carbohydrate content was estimated by difference [Carbohydrate (%) = 100% – % (moisture + crude protein + crude fat + ash)].

Determination of TPC

The Folin–Ciocalteau method was referred to determine the TPC of the samples (Ho, Abdul Aziz, & Azahari, 2013) with slight modifications. Samples were extracted using 70% methanol. Approximately one gram powdered sample was suspended into 100 ml of solvent. The extraction was carried out with stirring at room temperature for 24 h. The supernatants were filtered through Whatman No. 1 filter paper, and the filtrate was then collected for the TPC assay. A 0.4 ml sample of the extracts was added to the 3 ml of 2 M Folin–Ciocalteau reagent (pre-diluted to 0.2 M concentration with distilled water) and rested at room temperature for 5 min. After that, 4 ml of sodium carbonate (7.5% w/v) solution was added. The solutions were vortex mixed and allowed to stand for 90 min at room temperature. Gallic acid standard (at the concentrations of 0.2 to 1 mg/l) was prepared for a calibration curve. The absorbance was measured at 760 nm against a blank of methanol. The results were expressed as grams of Gallic acid equivalents per hundred grams of sample (mg GAE/kg sample).

Color analysis

The color indices of noodles were measured using a chromameter (Konica Minolta, CR-400) according to the CIE L* a* b* scale. All the samples were illuminated with D65-artificial daylight (10^5 standard angle). The equipment was calibrated using white ceramic tiles (Konica Minolta calibration plate) prior to analysis. The noodle samples were analyzed by placing on the petri dish. The color attributes such as lightness (L*), redness (a*), and yellowness (b*) values were recorded. The L* denotes lightness (0 = black, 100 = white), a* denotes the red/green value (+ value = redness, − value = greenness), and b* denotes the yellow/blue value (+ value = yellowness, − value = blueness).

Textural properties

Textural properties of cooked noodles were measured using a Texture Analyzer (Stable Micro System, TA-XT2, Surrey, UK) fitted with a 2.5 kg load cell. Measurements were conducted at room temperature exactly 15 min after cooking. A strand
of cooked noodle (1 mm thickness) was compressed by a cylinder probe (35 mm diameter) until the deformation reached 75% at a speed of 1 mm/s. The data of firmness and adhesiveness were analyzed using Texture Expert Version 1.05 Software (Stable Micro System Ltd, Surrey, UK). The textural properties of cooked noodles were determined with six replications.

**pH determination**

Approximately 10 g of the noodle samples was added to 100 ml of deionized water and stirred for 5 min. The pH of the filtrate sample was measured using Mettler-Toledo Delta 320 pH meter (Mettler-Toledo, Greifensee, Switzerland). The pH meter was prior calibrated using buffer solutions of pH 4.0 and 10.0.

**Cooking loss and cooking yield**

The cooking loss and cooking yield were determined as described by Zawawi et al. (2014). To determine cooking loss, 10 g sample of noodle was placed into 150 ml of boiling distilled water and cooked for 10 min. Cooking water was collected in a 250 ml volumetric flask, made to volume and shaken to homogenize the cooking water solution. A 10 ml solution was then measured into a pre-dried crucible and dried in an oven at 105 °C till a constant weight. The residue was weighed and reported as a percentage of the starting material (calculated by dry basis). For the analysis of cooking yield, the boiled noodle samples were removed from the cooking water and drained for 15 min, the weight was then evaluated and water sorption was expressed as the mass ratio before and after cooking.

**Sensory evaluation**

The sensory evaluation of the fresh noodles was conducted by 30 semi-trained panelists from the Faculty Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Malaysia. The sensory evaluation was performed using the seven-point hedonic scale as described by Watts, Ylimaki, and Jeffery (1989). The food samples were prepared in identical sample plates, coded with three-digit random numbers and each sample was presented with a different number. The randomized order of the sample was presented one at a time to each panelist. Panelists were asked to evaluate the coded noodle samples for each sensorial parameter based on their degree of liking (1 = dislike very much; 2 = dislike moderately; 3 = dislike slightly; 4 = neither like nor dislike; 5 = like slightly; 6 = like moderately; 7 = like very much). The attributes evaluated were cooked noodle color, chewiness, elasticity, surface smoothness, and overall acceptability.

**Statistical analyses**

Statistical analyses were conducted using Statistical Package for the Social Sciences version 14.0 software (SPSS Inc., Chicago, IL, USA). The results obtained from the present study are represented as the mean values of three individual replicates ± the standard deviation (S.D.), except for the textural properties measurement. One-way analysis of variance was performed and significant differences between the mean values were determined using Duncan’s multiple range tests at a significance level of p < 0.05.

**Results and discussion**

**Proximate composition and TPC**

The proximate composition and TPC of noodles incorporated with WRP are presented in Table 1. Moisture content of the noodles decreased significantly (p < 0.05) with incorporation of WRP at 100 and 150 g/kg levels to the noodles. This might be because of the lower moisture content of the WRP (106.1 g/kg) (Al-Sayed & Ahmed, 2013) than wheat flour (126.0 g/kg) (Ho & Noor Aziah, 2013). According to Rehman and Shah (1999), wheat flour has high moisture content due to its hygroscopic nature and presence of starch, therefore increasing the moisture content of the end-product.

As shown in Table 1, an increase in the substitution level of WRP for wheat flour resulted in a decrease in the protein content progressively from 146.8 to 129.1 g/kg. The values decreased from WRP0 (146.8 g/kg), WRP5 (137.6 g/kg), WRP10 (130.0 g/kg) to WRP15 (129.1 g/kg). This was because WRP contained lower protein (112.1 g/kg) (Hoque & Iqbal, 2015) than wheat flour (126.0 g/kg) (Ho & Noor Aziah, 2013). Hence, the substitution of WRP for wheat flour is expected to dilute the protein content of the composite noodles. A similar decreasing trend in the protein content of noodles made from incorporation of non-wheat flour (kenaf seeds

**Table 1. Proximate composition and total phenolic content of noodle samples.**

| Composition (g/kg) | WRP0 | WRP5 | WRP10 | WRP15 |
|-------------------|------|------|-------|-------|
| Moisture          | 344.2±0.12 | 350.9±0.39 | 327.3±0.16 | 322.9±0.69 |
| Crude Protein     | 146.8±0.22 | 137.6±0.42 | 130.0±0.12 | 129.1±0.17 |
| Crude Fat         | 21.3±0.03 | 20.0±0.02 | 25.2±0.28 | 26.5±0.03 |
| Ash               | 3.2±0.70 | 6.5±0.71 | 10.9±0.94 | 13.4±0.17 |
| Crude Fiber       | 1.0±0.02 | 7.6±0.20 | 16.7±0.08 | 24.2±0.21 |
| Carbohydrate      | 484.2±0.07 | 480.7±0.26 | 506.4±0.15 | 507.9±0.75 |
| Total Phenolic Content (mg GAE/kg dry sample) | 82.5±7.63 | 369.8±2.82 | 589.0±10.11 | 1164.0±6.15 |

Presented data are mean value of three replications ± standard deviation

Mean values in the same row with different superscript letters are significantly different (p < 0.05).

WRP0: Wet yellow noodle (control); WRP5: WRP0 substituted with 50 g/kg watermelon rind powder (WRP); WRP10: WRP0 substituted with 100 g/kg WRP; WRP15: WRP0 substituted with 150 g/kg WRP.

Los valores presentados son el valor promedio de tres repeticiones ± desviación estándar.

Los valores promedio en la misma fila con diferente superíndice son significativamente distintos (p < 0.05).

WRP0: Fideos húmedos amarillos (control); WRP5: WRP0 sustituido por 50 g/kg de corteza de sandía en polvo (WRP); WRP10: WRP0 sustituido por 100 g/kg de WRP; WRP15: WRP0 sustituido por 150 g/kg de WRP.
flour and sweet potato flour) with wheat flour was previously observed by Zawawi et al. (2014) and Ginting and Yulifianti (2015), respectively. The fat content of noodle samples was not significantly affected by substituting the wheat flour with WRP at 50 and 100 g/kg levels. WRP15 had significantly (p < 0.05) higher fat content (26.5 g/kg) than WRP0 (control) (21.3 g/kg). This was attributed to the high fat content (24.4 g/kg) of WRP (Hoque & Iqbal, 2013) than wheat flour (2.5 g/kg) (Ho & Noor Aziah, 2013). Thus, the replacement of WRP for wheat flour might contribute to the increment of fat content in composite noodles. In addition, the fat uptake is largely affected by the moisture content of the food, where water molecules serve as a protective barrier to prevent fat absorption (Mellema, 2003). Hence, the low moisture content of WRP0 was unable to provide a barrier coating for protecting oil penetration into composite noodle.

Ash content was significantly (p < 0.05) higher in WRP-containing noodles than in the control resulting from the higher ash in WRP (130.9 g/kg) (Al-Sayed & Ahmed, 2013) than wheat flour (5.6 g/kg) (Ho & Noor Aziah, 2013). The ash content depends on the quality of the flour (Kim, 1996) and thus corresponds to the higher mineral content in watermelon rind, which contributed to the significant higher ash content in WRP-containing noodles. According to Lakshmipathy and Sarada (2013), major minerals such as sodium, potassium, magnesium, and calcium, and other trace minerals (zinc and iron) are present in watermelon rind. The replacement of wheat flour with WRP at 50, 100, and 150 g/kg significantly (p < 0.05) increased the crude fiber content of the yellow noodles (Table 1), the contents being 1.0 g/kg (WRP0), 7.6 g/kg (WRP5), 16.7 g/kg (WRP10), and 24.2 g/kg (WRP15). As expected, this increase was because WRP was a good source of fiber (172.8 g/kg) (Al-Sayed & Ahmed, 2013) than the control (Ho & Noor Aziah, 2013). According to Hoque and Iqbal (2015), watermelon rind mainly consisted of oil and non-starch polysaccharides, cellulose, hemicelluloses, lignin, and other dietary fiber components. Dietary fiber plays a vital role in the human diet. Thus, indigestible polysaccharides in the watermelon rind could provide a variety of health benefits. The carbohydrate content in WRP-substituted noodles (WRP10 and WRP15) was significantly (p < 0.05) higher than those of the control (WRP0). Similar results were reported by Al-Sayed and Ahmed (2013); cakes incorporated with WRP have higher carbohydrate content than control. However, the composition of WRP and wheat flour is essential to be determined in order to understand their chemical properties prior to making a decision on the type of food product development.

Phenolic compounds consist of an aromatic ring, bearing one or more hydroxyl substituents ranging from simple to highly polymerized compounds and have been regarded as bioactive constituents in fruits and vegetables (Singh et al., 2015). TPC showed significant (p < 0.05) differences among samples (Table 1). TPC was the highest in the WRP15 noodle (1164.0 mg GAE/kg dry sample) and the lowest in WRP0 (control) (82.5 mg GAE/kg dry sample). Watermelon rind was reported by Al-Sayed and Ahmed (2013) to have high phenolic content due to the presence of abundant active components such as 4-hydroxybenzoic acid, vanillin, chlorogenic acid, sinapinic acid, P-anisic acid, hydroxycinnamic acid, caffeic acid, cinnamic acid, syringic acid, and coumaric acid. According to Rice-Evans, Miller, Bolwell, Bramley, and Pridham (1995), the phenolic compounds can predict its antioxidant activity based on availability of the phenolics to donate hydrogen. The findings indicated that WRP-containing noodles have higher antioxidative value than control. However, further studies are warranted to determine the antioxidant activity in WRP-containing noodles, which might provide more details.

Table 2. Physical properties of noodle samples.

| Parameter | WRP0 | WRP5 | WRP10 | WRP15 |
|-----------|------|------|-------|-------|
| Color     |      |      |       |       |
| L*        | 47.23±1.50 | 46.71±1.18 | 43.99±3.34 | 50.98±1.29 |
| a*        | −1.94±0.20  | −2.81±0.19  | −2.58±0.11  | −4.30±0.19  |
| b*        | 14.04±0.86  | 16.15±1.56  | 19.66±0.47  | 22.93±0.50  |
| Texture   |      |      |       |       |
| Firmness (N) | 54.65±2.61 | 48.70±1.16 | 38.45±3.68 | 28.10±2.35 |
| Adhesiveness (N/sec) | −0.32±0.04 | −0.36±0.11 | −0.20±0.05 | −0.12±0.07 |

Presented data are mean value of three replications ± standard deviation. Mean values in the same row with different superscript letters are significantly different (p < 0.05). WRP0: Wet yellow noodle (control); WRP5: WRP0 substituted with 50 g/kg watermelon rind powder (WRP); WRP10: WRP0 substituted with 100 g/kg WRP; WRP15: WRP0 substituted with 150 g/kg WRP.

Los datos presentados son el promedio de tres repeticiones ± desviación estándar. Los valores promedio en la misma fila con diferente superíndice son significativamente distintos (p < 0.05). WRP0: Fideos húmedos amarillos (control); WRP5: WRP0 sustituido por 50 g/kg de corteza de sandía en polvo (WRP); WRP10: WRP0 sustituido por 100 g/kg de WRP; WRP15: WRP0 sustituido por 150 g/kg de WRP.
sprout damage, and flour particle size (Kaushal & Sharma, 2014; Zhang et al., 2010).

The a* values of all the prepared noodles were negative, indicating that red hues were not present in the noodles. The WRP-containing noodles (WRP5, WRP10, and WRP15) had a significantly higher a* value (greenish) than the control (WRP0). The a* value increased proportionally with the WRP substituting level. This was attributed to the natural pigment color of WRP, which is greenish compared to wheat flour. According Yeoh, Alkarkhi, Ramli, and Easa (2011), the positive a* (red hues) value is undesirable and considered detrimental to the quality of alkaline noodles.

Table 2 presents a significant (p < 0.05) difference in b* values (yellowness) of noodles prepared from different formulations. The substitution of WRP for wheat flour (WRP5, WRP10, and WRP15) (16.15–22.93) resulted in significantly greater b* values than the control noodle (WRP0) (14.04). The alkaline noodles present their bright yellow color because of the apig ingenosides that undergo a chromophoric shift in the alkaline environment (high pH) to impart yellow color to the noodles (Yeoh et al., 2011). Alkaline salt in the noodles formulation can assist with the development of yellow color by detaching the flavone compounds (natural pigment) present in the flour. The degree of yellowness in noodles is affected by the type of alkaline salt used in the formulation, yellow pigment, and other flavonoid component (i.e., tricin) present in wheat flour (Miskelly, 1984).

Johnson et al. (2012) reported that watermelon rind contains high flavonoid (26.3 mg GAE/kg sample). Thus, the presence of natural yellow pigment (flavonoid) in WRP might have contributed to the yellow color of WRP-containing noodles. In addition, the results of b* value obtained from the present study showed a similar trend with those reported by Wandeet al. (2014), who reported that the pomelo peel-incorporated rice noodle possesses a greater yellow value (b*) than control.

Textural properties

The textural properties (firmness and adhesiveness) of the noodles are presented in Table 2. The firmness of the noodles was affected by the WRP substituting levels. WRP-containing noodles (WRP10 and WRP15) showed significantly (p < 0.05) lower firmness values (38.45 and 28.10 N, respectively) than the WRP0 (54.65 N), suggesting that composite noodles had a softer or tender texture. The lower value of firmness in composite noodles than the control might be attributed to a corresponding decrease in the amount of gluten as low protein powder (WRP) substitutions increased in wheat flour and also because of the fiber component in WRP, loosening the starch protein network. According to Ginting and Yulifianti (2015), wheat flour has high gluten content, which could result in more elastic noodle texture and therefore gain higher values of firmness. Firmness values obtained in the present study showed similarity with the results reported by Zawawi et al. (2014) for kenaf seeds flour-incorporated yellow noodles. In addition to protein-gluten content, the differences in textural properties of the noodles could also be attributed to the dilution of starches consequently of amylose. Textural properties of starch noodles have been reported to be influenced with amylose content as well as the incorporation of hydrocolloids (soluble fiber such as gums). Kaur, Shevkani, Singh, Sharma, and Kaur (2015) reported that noodles prepared from flour containing starches high in amylose have higher values of firmness than the noodles made from flour containing low amylose.

Noodle stickiness can be measured as adhesiveness in the profile of the Texture Profile Analysis (the area of the negative peak) (Ma et al., 2014). The replacement of the WRP for wheat flour at 100 and 150 g/kg had significantly (p < 0.05) decreased adhesiveness of the composite noodles from ~0.32 N/s (WRP0) to ~0.20–0.12 N/s (WRP10 and WRP15, respectively) (Table 2). Adhesiveness of noodles usually results from swelling of amylose and its leaching onto the surface of the noodle strands. Fiber in the WRP could lead to dilution of starch, which coupled with the competitive hydration of starch and fiber might also have led to the low stickiness. This was attributed to the lower moisture content of composite noodles (WRP10 and WRP15) than control (WRP0) (Table 1). According to Utomo (2009), moisture content of the sample is positively correlated with its adhesive- ness. A significant positive correlation between adhesiveness and cooking loss (Table 3) was observed in the present study. Similar results have been previously reported by Ma et al. (2014), a decrease in adhesiveness due to the presence of non-wheat flour (millet and corn flour) in wheat noodle.

Table 2. pH values and cooking properties of noodle samples.

| Sample  | pH       | Cooking Yield (g/kg) | Cooking Loss (g/kg) |
|---------|----------|----------------------|---------------------|
| WRP0    | 8.10±0.20| 1356.6±2.36          | 20.2±1.83           |
| WRP5    | 7.39±0.26| 1366.1±11.54         | 19.0±0.21           |
| WRP10   | 7.12±0.25| 1401.8±1.05          | 15.2±0.00           |
| WRP15   | 7.03±0.15| 1412.4±10.46         | 15.4±0.83           |

Presented data are the mean value of three replications ± standard deviation. Mean values in the same column with different superscript letters are significantly different (p < 0.05). WRP0: Wet yellow noodle (control); WRP5: WRP0 substituted with 50 g/kg watermelon rind powder (WRP); WRP10: WRP0 substituted with 100 g/kg WRP; WRP15: WRP0 substituted with 150 g/kg WRP.

Los datos presentados son el valor promedio de tres replicas ± desviación estándar. Los valores promedio en la misma columna con diferente superíndice son significativamente distintos (p < 0.05). WRP0: Fideos húmedos amarillos (control); WRP5: WRP0 sustituido por 50 g/kg de corteza de sandía en polvo (WRP); WRP10: WRP0 sustituido por 100 g/kg de WRP; WRP15: WRP0 sustituido por 150 g/kg de WRP.
Graybosch, and Parkhurst (2003), high stickiness value of the cooked noodles is an undesirable quality and considered detrimental to eating quality.

**pH values**

The pH values of cooked noodles are presented in Table 3. pH has been considered as an important factor affecting the dough strength, with higher values suggesting tougher dough through strengthening the bonding forces within the starch granules. This then leads to a firmer texture of the cooked noodles. The presence of WRP in formulation had an influence on the pH values of the composite noodles. WRP-containing noodles (7.39, 7.12, and 7.03 for WRP5, WRP10, and WRP15, respectively) had significantly (p < 0.05) lower pH values than the control noodle (without WRP) (8.10). According to Miskelly (1996), the typical pH values of yellow alkaline noodles range from approximately 9 to 11, due to the presence of alkaline salts. Statistical results indicated that all the composite noodles had lower pH than the typical range of commercial yellow alkaline noodles. This was attributed to the functional properties of WRP. Al-Sayed and Ahmed (2013) reported that WRP has high water absorption capacity and hence dilution of alkaline salts can occur in the noodles. Thus, this might reduce the alkalinity of the samples. The pH values of the composite noodles gradually decreased with increasing WRP substitution. This was attributed to the gluten fraction being diluted (Kovacs, Fu, Woods, & Khan, 2004) in composite noodles and hence weakening the network (protein-starch network) within the noodles to hold the alkaline salts.

**Cooking quality**

The results of cooking yield and cooking loss of the noodles are presented in Table 3. The substitution of WRP for wheat flour at the levels of 50, 100, and 150 g/kg did not affect the cooking yield (1366.1, 1401.6, and 1412.4 g/kg for WRP5, WRP10, and WRP15, respectively) of the noodles compared to the control (WRP0) (1356.6 g/kg). According to Chin, Huda, and Yang (2012), noodle with high cooking yield value represents its ability to absorb water and this value is negatively proportional to the flour protein content. Low cooking yield is an undesirable cooking quality due to poor water-binding capacity and this is then results in chewy, hard-textured noodles (Wandee et al., 2014). Zawawi et al. (2014) proposed that incorporation of kenef seeds flour at 250 and 750 g/kg into the noodles can help increase the cooking yield. However, the presence of WRP in noodles did not affect the cooking yield since the proportion of WRP used was rather low (150 g/kg).

Cooking loss indicates the ability of the noodles to maintain structural integrity during the cooking process (Wandee et al., 2014). All the WRP-containing noodles, with the exception of WRP5, had significantly (p < 0.05) lower cooking loss values than the control. According to Ma et al. (2014), cooking loss is undesirable and it should not exceed 10% of the dry weight sample. A low cooking loss in cooked noodles is desirable as it shows low solubility of starch, resulting in clear (less turbid) cooking water (Zawawi et al., 2014). Thus, the partial replacement of wheat flour with WRP can improve the quality of noodles. According to Shiau and Yeh (2001), the cooking loss property reflects the surface characteristics of the noodles. The higher the cooking loss is, the sticker the noodle surface and the resulting sticky mouth feel. Thus, the cooking loss results obtained in the present study are in agreement with the adhesiveness results provided in Table 2, where a positive correlation between adhesiveness and cooking loss of noodles was observed. This might be attributed to the presence of foreign material such as fiber from WRP, which is a highly water-binding macromolecule, competes with starch for water absorption, thereby limiting the available water for starch granules to completely swell (Kaur et al., 2015), and consequently less amylose leaching (low cooking loss) and decreased the adhesiveness of the noodles. Majzooob, Ostovan, and Farahnaky (2011) also found a positive correlation between the cooking loss and adhesiveness.

**Sensory quality of noodles**

The sensory scores for the attributes color, chewiness, elasticity, smoothness, and overall acceptability of the cooked noodles are tabulated in Table 4. Color of the noodles was significantly affected by substituting flour due to its bright-yellow color. It was observed that the WRP-containing samples exhibited higher color scores (3.40–3.63) than the control (2.96). The panelists rated the noodle prepared from wheat flour (WRP0) as moderately disliked for color. The color of the noodle is an important sensory attribute for consumers. Asian consumers perceived noodles as either light yellow or dark (gray) and have preferences depending on which type the noodle appears to be. For example, consumers expect buckwheat noodle to have a dark (gray)

| Attribute | WRP0 | WRP5 | WRP10 | WRP15 |
|-----------|------|------|-------|-------|
| Color     | 2.96±0.18 | 3.63±0.96 | 3.53±0.89 | 3.40±0.89 |
| Chewiness | 4.25±0.17 | 4.00±0.25 | 4.06±0.22 | 3.55±0.77 |
| Elasticity| 4.56±0.13 | 3.90±0.12 | 4.50±0.27 | 4.16±0.01 |
| Smoothness| 3.46±0.33 | 3.66±0.09 | 4.10±0.02 | 3.46±0.10 |
| Overall acceptability | 5.34±0.76 | 4.66±0.60 | 6.33±0.75 | 4.93±1.01 |

Table 4. Sensory evaluation of noodle samples.

Legend: Mean values in the same row with different superscript letters are significantly different (p < 0.05).

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WRP0: Wet yellow noodle (control); WRP5: WRP0 substituted with 50 g/kg watermelon rind powder (WRP); WRP10: WRP0 substituted with 100 g/kg WRP; WRP15: WRP0 substituted with 150 g/kg WRP.

Los valores promedio en la misma fila con diferente superíndice son significativamente distintos (p < 0.05).

WRP0: Fideos húmedos amarillos (control); WRP5: WRP0 sustituido por 50 g/kg de corteza de sandía en polvo (WRP); WRP10: WRP0 sustituido por 100 g/kg de WRP; WRP15: WRP0 sustituido por 150 g/kg de WRP.
color and may reject a light-colored buckwheat noodle. Assuming that is the case, consumers may prefer yellow noodle with the incorporation of WRP, which would be light yellow in color.

According to Wandee et al. (2014), the effect of fiber-rich ingredient incorporation on noodle quality depends on the amount of fiber added. The partial replacement of wheat flour with WRP at 150 g/kg level significantly reduced the sensory score (3.53) of chewiness. Earlier, Baik, Powers, and Nguyen (2004) reported a linear relationship between protein content and chewiness, where the flour protein content affects the chewiness. The partial replacement of wheat flour with WRP might dilute the protein content and subsequently interfere with gluten network formation. Hence, less energy is required to masticate the weak and tender composite noodles to the state ready for swallowing. This result is similar to that obtained by Aydin and Gocmen (2011), who reported that the score of chewiness attribute for noodle decreased with increasing level of oat flour substituted for wheat flour. It was concluded from the study that consumers preferred noodles with harder texture giving a chewy mouthfeel to the cooked product.

The sensory panels indicated a slightly lower score (3.90–4.50) for the elasticity of composite noodles (WRP5, WRP10, and WRP15). The results obtained in the present study were consistent with the results of previous reports by Zhang et al. (2010). Zhang et al. (2010) reported that the elastic evaluation score of sweet potato flour-incorporated noodles decreased significantly compared to the control noodle. Gluten is the important protein imparting elasticity to noodles. Thus, the low elasticity score of the composite noodles was due to the substitution of gluten-free ingredient (WRP) for wheat flour leading to gluten dilution in noodle dough.

No significant differences were found among all the noodle samples for smoothness attribute. The partial substitution of WRP for wheat flour in noodle preparation did not affect the smoothness perceptions during consumption. Smoothness score of noodles varied from 3.46 to 4.10 (Table 4). According to Zhang et al. (2010), the smoothness relates to the stickiness property of the cooked noodle. Thus, the results from smoothness attribute were in good agreement with the results of cooking loss (Table 3).

Overall, all the formulations were acceptable as they received scores greater than 4, ranging from 4.93 to 6.33. The panelists rated WRP10 as having the highest score (6.33), indicating ‘like moderately’ for overall acceptability due to the relatively yellow color, lower chewiness, elasticity, and surface smoothness scores obtained. It could be concluded from the study that the panelists accepted the noodles prepared from WRP with a substitution level of 100 g/kg, indicating the potential of WRP as a functional additive in noodle preparation. Therefore, it is possible to satisfactorily produce healthy wet yellow noodles by using 50–100 g/kg of WRP.

### Conclusion

The partial substitution of wheat flour with WRP had an impact on the physicochemical and sensory attributes of the wet yellow noodles. WRP-containing noodles had higher levels of proximate components (fat, ash, fiber, and carbohydrate) and TPC than the control (noodle without WRP), indicative of the high nutritive value of the fortified products. The partial replacement of wheat flour with WRP did not alter the lightness (L*) values of composite noodles. However, the a* and b* values indicated a shift toward the green (-a*) and yellow (+b*) quadrats, respectively, as the replacement level of WRP content increased in composite noodles. Firmness and adhesiveness values of composite noodles decreased as the WRP content increased. Although the substitution of wheat flour with WRP improved the quality of end-products, the presence of WRP decreased the pH values of composite noodles. Noodles made from the partial substitution of wheat flour with WRP at 100 g/kg (WRP10) had the greatest acceptability ratings (6.33) by the panelists. The present study provides useful information for the future development of WRP–wheat-flour-based food products such as cakes, muffins, pastries, and other bakery products, which have numerous beneficial effects on human health.

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### Disclosure statement

No potential conflict of interest was reported by the authors.

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