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## FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

# Development and evaluation of African palmyra palm (*Borassus aethiopum*) fruit flour–wheat composite flour noodles

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**Abstract:** *Borassus aethiopum* (African palmyra palm (APP)) fruit is an underutilized tropical fruit but has potential food applications. In the present work, the suitability of APP fruit–wheat composite flour in the development of noodles was investigated. The fresh APP fruit pulp was separated, oven-dried at 60°C and milled into flour. The obtained flour was mixed with commercial wheat flour to obtain three composite flours with 5%, 10% and 15% of APP fruit flour. The functional properties and proximate composition of the composite flours were determined. The cooking properties and consumer preference of the noodles developed were also evaluated. The cooking yield, water uptake and gruel solid loss ranged from 259.81% to 300.97%, 159.81% to 200.97% and 11.52% to 17.11%, respectively. The water absorption capacities, swelling power and the solubility indices of the flours ranged from 197.10% to 492.66%, 621.99% to 734.91% and 4.53 to 26.48%, respectively. On the 7-point hedonic scale, the flavour, smell, colour and overall acceptability ranged between 4.2 and 5.3, 4.8 and 5.65, 4.05 and 5.3 and 4.10 and 5.03, respectively. The inclusion of APP fruit flour at 5% level yielded noodles with enhanced nutritional quality and highest overall consumer acceptability.

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## PUBLIC INTEREST STATEMENT

Noodles are one of the most widely consumed foods in the world. They have been fortified with various ingredients for the purpose of product diversity and nutritional enhancement. The flour prepared from African palmyra palm (APP) (*Borassus aethiopum*) fruits which mostly go waste (about 60–70%) was used in noodle making in this study. It was demonstrated that acceptable noodle products could be produced from 5% APP-fruit-flour:95% wheat flour. The incorporation of APP fruit flour enhanced the flavour, taste and overall acceptability of noodles. This highlights the potential utilization of APP fruit flour in noodle making to reduce its wastage and contribute food security as well as diversity in the existing noodle products. Food manufacturers and related stakeholders should, therefore, put efforts in place to promote the utilization of APP fruits in the noodle industry.

**Subjects:** Sensory Science; Substitutes - Food Chemistry; Food Analysis

**Keywords:** *Borassus aethiopum*; composite flour; noodles; food waste; underutilized tropical fruits

## 1. Introduction

The World Health Organization has estimated that the world's population is to reach over 9 billion by 2050. Consequently, the works of global food organisations as well as scientists, especially agricultural scientists, postharvest technologists, food scientists and processors, are aimed at ensuring sufficient supply of healthy foods to match this expected world population. Among some of these works include genetic modification of crops to increase yield, drought and disease resistance as well as shorten maturity time and development of storage and processing methods to reduce postharvest losses of horticultural produce. Besides, researchers have also considered value addition via processing and product development to increase the utilization of underutilised and neglected edible tropical fruits including the African palmyra palm (APP) (*Borassus aethiopum* Mart) fruits (Abe-Inge et al., 2018a, 2018b; Adzinyo et al., 2015; Ali et al., 2010a, 2010b, 2010c).

Although not cultivated commercially, APP grows widely in the wild across Ghana as well as in most other West African countries such as Senegal, Benin, Cote D'Ivoire, Cameroon and Nigeria (Ali et al., 2010a; Djibrilla, 2006; Gbesso et al., 2016; Siaw et al., 2014). In its regions of growth, it is predominant in the forest zones of these tropical regions. Siaw et al. (2014) reported that it had a population density of about 18–61 trees/hectare in the Mampong Forest District of Ghana. According to Djibrilla (2006), Ali et al. (2010c) and Quinsavi et al. (2011), the matured female APP has fruits between 50 and 350 fruits/per tree once in every 8 months. Its fresh fruits are high in moisture and rich in fibre, minerals and vitamins (Ali et al., 2010a), whereas its fruit flour was also reported to be rich in antioxidants, dietary fibre, minerals and bioactive compounds (Abe-Inge et al., 2018a, 2018b).

Currently, in some rural communities of Ghana, APP fruits are used either raw or boiled with corn or porridge. However, recent research works aimed at increasing the utilization of the fruits led to the developments of some acceptable food products such as syrup, spread, jam (Adzinyo et al., 2015) and a functional bread (Pepra et al., 2018) from the fresh fruit pulp and the dried fruit pulp flour, respectively. According to Abe-Inge et al. (2018a) who investigated the potential applications of the APP fruit flour in the food industry, based on its good swelling and water absorption properties, the flour is suitable for use in developing noodles.

Noodles are widely consumed across the world. It is often consumed either alone or with other foods such as boiled rice. In Ghana, it is also boiled and served with a popular street-vended food called waakye (a dish prepared from boiling specific variety rice and cowpea together). Noodles are globally believed to originate from China and subsequently spreading to other parts of the world due to globalisation of trade (Onyema et al., 2014). Noodle, therefore, is a popular Chinese staple traditional food. Wheat flour (WF), water and salt are the basic ingredients for noodle making. However, for the purposes of finding alternative lower-cost ingredients, diversity and nutritional enhancement, researchers have innovatively incorporated noodles with other ingredients including cowpea flour, lentil seed flour, breadfruit flour, orange-fleshed sweetpotato flour, spirulina flour, spinach puree and jamun seed flour (Mbaeyi-Nwaoha & Ugwu, 2018; Onyema et al., 2014; Shahsavani & Mostaghi, 2017; Shere et al., 2018; Sood et al., 2018; Tijani et al., 2017). The incorporation of these ingredients enhanced some nutritional parameters including the protein, dietary fibre, ash and carbohydrate contents as well as some sensory characteristics of noodles.

Despite earlier reports of its great potential applications in the food industry, there is limited scientific-based evidence of the suitability of APP fruit flour in noodle making. Therefore, the objective of this study was to investigate the suitability of APP fruit-wheat composite flour in noodle making.

## 2. Materials and methods

### 2.1. Source of materials

APP fruits were obtained from Congo 3 in the Ejura-Sekyedumase district in the Ashanti Region of Ghana. All equipment and chemical reagents for APP fruit flour processing, noodle production and laboratory analysis of samples were obtained from the Food Science Laboratories of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

### 2.2. Sample preparation

#### 2.2.1. APP fruit flour preparation

The fruits were washed and the pulp was removed using a stainless steel kitchen knife. The pulp was cut into pieces, spread evenly on a drying tray and dried in a hot-air oven (Binder Heating and Drying Oven, serial no: 15-18440, Tuttlingen, Germany) at 60°C for 6 hours. The dried pulp was milled using a kitchen blender (Binatone, model no: BLG-555, China), sieved with a sieve of 425- $\mu$ m-pore-size mesh, double packaged in Ziploc bags and stored at 4°C for further use.

#### 2.2.2. Flour formulation and ingredient combinations

The APP fruit-wheat composite flours were formulated to achieve 5%, 10% and 15% of APP fruit flour on flour basis as shown in Table 1.

#### 2.2.3. Noodle preparation

Noodles were prepared using the method as described by Shahsavani and Mostaghi (2017) with modifications. APP fruit flour was incorporated into hard WF at 5%, 10% and 15% to develop a composite flour, whilst all the other ingredients were kept constant for each sample (iodinated salt (NaCl), 1 g; honey, 10 g; and water, 50 g). All ingredients were brought to room temperature by leaving on the working bench for an hour. Iodinated salt was dissolved in the water, and together with other ingredients, they were mixed. The mixture was then rolled to form dough. The prepared dough was kneaded for 10 minutes at low speed with a hand mixer (Model: D-20095) and rested for 5 minutes. The dough was sheeted and made into thin strips of about 2 mm in width, 3 mm in thickness and 7 cm in length using a pasta maker (Master Chef; Crown Star model MC 8830, China). The strips were coated with dry flour to prevent them from sticking together. The fresh noodles were steamed at 105°C for 5 min using the 3-in-1 Healthy Multi-Cooker steamer (Model: MCS 1850, Binatone, China) and oven-dried in a toaster oven (Black +Decker, Model TRO1000, China) at 80°C for 2 h to obtain a crispy noodle. The dried noodles were allowed to cool and stored in an airtight container for further analysis.

### 2.3. Determination of functional properties of flours

#### 2.3.1. Water absorption capacity

One gram of each flour was weighed into a pre-weighed washed and air-dried 15 mL capacity centrifuge, and 10 mL of distilled water was added. The mixture was vortexed for 5 min to ensure uniform mixing of water with the flour sample and then centrifuged at 2,200 rpm for 30 min. The

**Table 1. Flour formulation and ingredient combinations**

Ingredients (g)	WF	F5	F10	F15
Wheat flour	100	95	90	85
APP fruit flour	0	5	10	15
Salt (NaCl)	1	1	1	1
Honey	10	10	10	10
Water	50	50	50	50

supernatant was carefully decanted and the sediment together with the tube weighed. The weight of the sediment/paste was determined. Water absorption capacity (WAC) was calculated as

$$\%WAC = \frac{\text{Weight of paste}}{\text{Initial weight of flour sample}} \times 100$$

### 2.3.2. Swelling power and solubility index

One gram of each flour was weighed into a pre-weighed 15 mL capacity centrifuge tube and 10 mL distilled water was added. The suspension was vortexed at low speed for 1 min. The suspension was heated in a thermostatically controlled shaking water bath at 85°C for 30 min. The tubes were removed and cooled to room temperature and then centrifuged at about 2,200 rpm for 15 min. Each supernatant was gently decanted into a clean dried pre-weighed petri dish and evaporated to dryness in an oven at 105°C. The dried supernatant was cooled and weighed. The paste obtained after centrifugation and decantation of supernatant was also weighed.

$$\text{Swelling power (\%)} = \frac{\text{wt of sedimented flour paste}}{\text{wt of dry flour sample taken}} \times 100$$

$$\text{Solubility index (\%)} = \frac{\text{wt of dried supernatant}}{\text{wt of flour sample taken}} \times 100$$

### 2.3.3. Tapped bulk density

Ten grams of each flour were weighed into 50 mL graduated measuring cylinder. The measuring cylinder together with the sample was tapped gently on the benchtop 10 times after which the volume of the sample was recorded.

$$\text{Tapped bulk density (g/mL)} = \frac{\text{Weight of sample}}{\text{Volume of tapped sample}}$$

### 2.3.4. Pasting profile

Pasting properties of the flours were determined according to Alamri et al. (2012) using the Rapid Visco-Analyzer (RVA Model 4500, Perten Instruments, Australia) on a 14% moisture basis. The flour samples with known moisture contents were directly weighed (3 g) into RVA canisters and about 25 g of distilled water was added to reach a total weight of 28 g. The canister paddle was inserted and the whole canister assembled into the RVA. The weight of distilled water added depended on the moisture content of the flour. The total run time was 23 min. The viscosity was recorded as temperature increased from 50°C to 95°C during the heating phase and decreased from 95°C back to 50°C during the cooling phase. The rotation speed for the first 10 s was 960 rpm and 160 rpm for the rest of the run time. All measurements were done in duplicate.

## 2.4. Proximate composition of flours and noodles

Proximate composition (moisture, ash, crude fat, crude fibre and carbohydrate contents) determination was carried out according to AOAC methods (AOAC, 1990). Crude protein was calculated by multiplying the obtained nitrogen content by 6.25. Available carbohydrate content was calculated by difference.

## 2.5. Cooking properties of noodles

Noodle cooking properties (cooking yield, water uptake and cooking loss) were assessed following recommendations by Zhang et al. (2012) in their study. Cooking yield and cooking loss of the noodles were determined as described in the American Association of Cereal Chemists (AACC, 2000) methods with modifications. Noodles (2.5 g) were added to a beaker containing about 50 ml boiling water. The beaker was covered with an aluminium foil and cooked for 10 minutes with slight agitation. The cooked noodles were allowed to drain and cool for 10 minutes and then

weighed. The cooking yield and water uptake were then calculated. Gruel from the cooked noodles was drained directly into an aluminium dish of about 100 mL capacity. The dish, together with the gruel, was dried at 105°C to a constant weight, cooled and weighed. The cooking loss during cooking was also calculated using the following formula:

$$\text{Cooking yield (\%)} = \frac{\text{Weight after cooking}}{\text{Weight before cooking}} \times 100$$

$$\text{Cooking loss (\%)} = \frac{\text{Weight of dried gruel and dish} - \text{Weight of dish}}{\text{Weight of sample}} \times 100$$

$$\text{Water uptake (\%)} = \frac{\text{Weight after cooking} - \text{Weight before cooking}}{\text{Weight before cooking}} \times 100$$

## 2.6. Sensory evaluation of noodles

The sensory panel was made up of 20 semi-trained panellists comprising 11 females and 9 males in the age group 20–25. The panellists evaluated the noodle based on the attributes such as colour, appearance, texture, aftertaste, smell, firmness and flavour using the 7-point hedonic scale, where 1—dislike very much, 2—dislike moderately, 3—dislike slightly, 4—neither like nor dislike, 5—like slightly, 6—like moderately and 7—like very much. Samples were prepared by cooking 50 g of the dried instant noodle in 300 mL boiling water for 5 minutes and draining the water. The cooked drained noodles were served warm (40–50°C) in transparent plastic bowls and water was used as a pallet cleanser after tasting each sample before tasting the next. The overall mean scores of the noodle products were obtained by calculating the average of the scores obtained for the various attributes.

## 2.7. Statistical analysis

The independent sample *t*-test was used to analyse the data on proximate composition of the most preferred noodle and the control noodle, whereas one-way analysis of variance (ANOVA) was carried out for all other data. Tukey's test was used for multiple comparison and separation of means. All analyses were carried out at 5% significance level ( $\alpha = 0.05$ ) using the Statistical Package for Social Sciences (SPSS, IBM SPSS Statistics v20).

## 3. Results and discussion

### 3.1. Proximate composition of APP fruit flour, wheat flour and APP fruit–wheat composite flours

The proximate composition of the APP fruit–wheat composite flour is shown in Table 2. The ash, moisture, crude fibre, crude fat, crude protein and carbohydrate ranged from 0.56% to 3.35%, 5.06% to 7.97%, 0.24% to 14.45%, 1.05% to 2.13%, 3.66% to 10.77% and 71.36% to 79.80%, respectively. The APP fruit flour recorded the highest ash, crude fibre and crude fat contents of 3.35%, 14.45% and 2.13 %, respectively, but also recorded the least crude protein and available carbohydrate contents. At 5% significance level ( $\alpha = 0.05$ ), there were significant statistical differences among all the proximate parameters. The inclusion of WF significantly increased the ash, crude fibre and crude fat but decreased the crude protein of the obtained APP fruit–wheat composite flours. There was, however, no significant difference ( $p > 0.05$ ) among the moisture and available carbohydrate values of the composite flours (F5, F10, F15) and the 100% WF.

#### 3.1.1. Ash

Ash is a measure of the total inorganic matter in a food material, which, in turn, is the total mineral content of the food. The ash content ranged from 0.56% in the 100% WF to 3.35% in the APP fruit flour. There was a significant ( $p < 0.05$ ) increase in the ash content as the percentage of APP fruit flour inclusion increased. This could be attributed to the higher ash content (3.35%) of the APP fruit flour than the 100% WF. This value was within the 2.51–4.14%

**Table 2. Proximate composition of APP fruit flour, wheat flour and APP-fruit-wheat composite flours**

Flour	Ash (%)	Moisture (%)	Fibre (%)	Fat (%)	Protein (%)	CHO (%)
APPF	3.35 ± 0.01 <sup>a</sup>	5.06 ± 0.21 <sup>a</sup>	14.45 ± 0.01 <sup>a</sup>	2.13 ± 0.18 <sup>a</sup>	3.66 ± 0.11 <sup>a</sup>	71.36 ± 0.28 <sup>a</sup>
WF	0.56 ± 0.01 <sup>b</sup>	6.79 ± 0.00 <sup>ab</sup>	0.24 ± 0.01 <sup>b</sup>	1.85 ± 0.00 <sup>ab</sup>	10.77 ± 0.24 <sup>b</sup>	79.80 ± 0.24 <sup>b</sup>
F5	0.78 ± 0.01 <sup>c</sup>	7.97 ± 0.19 <sup>b</sup>	1.37 ± 0.07 <sup>c</sup>	1.05 ± 0.18 <sup>c</sup>	10.66 ± 0.00 <sup>b</sup>	78.19 ± 0.43 <sup>b</sup>
F10	0.93 ± 0.93 <sup>d</sup>	7.37 ± 0.96 <sup>b</sup>	1.68 ± 0.04 <sup>d</sup>	1.07 ± 0.00 <sup>c</sup>	10.05 ± 0.18 <sup>c</sup>	78.90 ± 1.13 <sup>b</sup>
F15	1.03 ± 0.00 <sup>e</sup>	7.47 ± 0.10 <sup>b</sup>	2.79 ± 0.06 <sup>e</sup>	1.39 ± 0.12 <sup>bc</sup>	8.80 ± 0.09 <sup>d</sup>	78.53 ± 0.25 <sup>b</sup>

Notes: All data are means of two replicates; means with the same superscripts in a column are not significantly different ( $p > 0.05$ ). APPF: African palmyra palm fruit flour; WF: 100% wheat flour; F5: 95% wheat flour; 5% APPF; F10: 90% wheat flour; 10% APPF; F15: 85% wheat flour; 15% APPF; CHO: available carbohydrate.

range of ash content reported for APP fruit flours produced from different drying methods in an earlier study (Abe-Inge et al., 2018a). According to the previous findings, the total mineral content affects the development of the characteristic bright yellow color and whiteness of noodles (Lee et al., 1987; Morris et al., 2000; Oh et al., 1985b). Although higher ash content is associated with greater noodle discoloration (Morris, 2018), it also improves the texture of noodles and flour starch pasting properties (Morris et al., 2000). According to Abe-Inge et al. (2018b), hot-air oven-dried APP fruit flour contained 268.44 mg/100 g potassium, 211.76 mg/100 g magnesium, 80.84 mg/100 g calcium and 33.38 mg/100 g sodium. Therefore, the increase in ash could also lead to an increase in the potassium, magnesium, calcium and sodium content and hence a boost in the total nutritional value of noodles.

### 3.1.2. Moisture

Moisture is a measure of the water content in the food material. It is also an indicative measure of the shelf life of a food material (Adebawale, Adeyemi, et al., 2005). The recorded moisture values for the APP fruit-wheat composite flours (F5, F10, F15) ranged from 7.37% to 7.97% and were statistically the same ( $p > 0.05$ ) as the moisture content of the 100% WF. These values were in the 6.00–8.50% range reported by Yadav et al. (2014) for wheat blends with colocasia, water chestnut and sweetpotato flours. Flours with lower moisture have greater shelf stability since spoilage is often caused by microbial activities and related chemical reactions that require higher moisture levels.

### 3.1.3. Crude fibre

Crude fibre content ranged from 0.24% to 100% WF to 14.45% in the APP fruit flour (APPF). The inclusion of APP fruit flour into WF significantly increased the crude fibre content. This was due to the high crude fibre content (14.45%) of APP fruit flour as shown in Table 2. Crude fibre influences the cooking loss of noodles. Higher crude fibre increases the cooking loss (Shahsavani & Mostaghi, 2017) by interfering with the protein–starch complex essential for a strong dough formation. A similar observation was made in this study as cooking loss increased with an increased APP fruit flour inclusion (crude fibre content) as shown in Table 7. However, higher dietary fibre in foods is also essential in the prevention of type II diabetes (Yao et al., 2014), constipation, cardiovascular diseases (Threapleton et al., 2013), stroke (A. Zhang et al., 2013), obesity (Sudha et al., 2011) and cancer. Dietary fibre has been reported to be preventive against colon cancer (Wong et al., 2006) and colorectal cancer (Dahm et al., 2010). Therefore, the consumption of fiber-rich noodles could help prevent the above-mentioned diseases.

### 3.1.4. Crude fat

Crude fat ranged from 1.05% in the 5% APP fruit composite flour (F5) to 2.13% in the 100% APP fruit flour. Generally, there was a significant difference among all recorded crude fat values. However, the difference between the values recorded for F5, F10 and F15 was insignificant. The majority of previous works on noodles paid little attention to the crude fat content of noodle flour probably due to its low levels in noodle flour as well as its little influence on the quality of noodles. Fat contributes to the flavour and mouthfeel of many food products including instant fried noodles and also to the shelf stability of a food material. Foods with lower crude fat contents have a greater shelf stability against spoilage via lipolysis-induced oxidative reactions (Abe-Inge et al., 2018a).

### 3.1.5. Crude protein

The crude protein content of APP fruit-wheat composite fruit flours ranged from 3.66% in the 100% APP fruit flour to 10.77% in the 100% WF. Crude protein decreased significantly with an increased inclusion of the APP fruit flour. This could be due to the low crude protein content (3.66%) of APP fruit flour. Protein plays a key role in the quality characteristics of noodles. It has been reported to influence the textural characteristics and cooking quality of noodles (Asenstorfer et al., 2010; Li et al., 2014; Wang et al., 2004). This influence is mainly due to WF protein (Yeoh et al., 2011). Gluten protein which is the dominant protein in WF greatly influences dough quality characteristics

in noodle making. The subunits of gluten—gliadins and glutenins—interact to form a gluten network essential for a strong dough formation which in turn is necessary for making noodles with good firmness and eating quality. Besides, noodle flour protein quality and quantity have an influence on the Maillard browning of dried noodles and water and fat absorption capacities.

### 3.1.6. Available carbohydrate

The total available carbohydrate content of the flours ranged from 71.36% in the 100% APP fruit flour (APPF) to 79.80% in the 100% WF. The inclusion of APP fruit flour demonstrated an insignificant effect on the total available contents of the 100% WF and all the composite flours. The slight variation in the available carbohydrate values was attributable to the variation in the values for the other proximate parameters since the available carbohydrate determination was done by difference. Flour starch quantity and quality influence dough characteristics, noodle processing conditions and cooking quality (Hatcher et al., 2002). Flour carbohydrate content in the form of starch influences flour parameters such as water absorption, swelling characteristics and pasting properties which in turn influence noodle quality (Bettge, 2003; Crosbie, 1991; Hatcher et al., 2002).

## 3.2. Functional properties of APP fruit flour, wheat flour and APP fruit–wheat composite flours

### 3.2.1. Water absorption capacity

The WAC of the control and composite flours ranged from 180.69% to 492.66% with WF recording the lowest value and 100% APP fruit flour recording the highest value (Table 3). WAC of composite flours increased as percentage substitution with APP fruit flour increased. APP fruit flour recorded a higher WAC than WF in this study and this corroborates a similar earlier finding reported by Abe-Inge et al. (2018a). WAC is associated with amylose solubility and leaching as well as loss of starch crystalline structure (Chandra et al., 2015). Therefore, the increase in WAC of the composite flours with increasing incorporation of APP fruit flour may be attributed to increased amylose leaching and solubility and loss of starch crystalline structure. The relatively high WAC of the composite flours makes them suitable functional ingredients in products where good viscosity is required such as soups, gravies, cheese and yoghurt.

### 3.2.2. Swelling power and solubility index

APP fruit flour recorded the highest value (26.48%) of solubility index with the least value (4.53%) recorded for WF (Table 3). The solubility index of the composite flours increased with increasing substitution of the APP fruit flour. The swelling power of the flour ranged from 621.99% to 734.91% with 100% APP fruit flour recording the least value and 100% WF recording the highest value, respectively. However, the solubility index of the 100% WF was observed to be the least and the

**Table 3. Functional properties of APP fruit flour, wheat flour and APP fruit–wheat composite flours**

Flour	SI (%)	WAC (%)	SP (%)	BD (g/mL)
APPF	26.48 ± 0.13 <sup>a</sup>	492.66 ± 4.29 <sup>a</sup>	621.99 ± 8.62 <sup>a</sup>	0.72 ± 0.00 <sup>a</sup>
WF	4.53 ± 0.09 <sup>b</sup>	180.69 ± 2.38 <sup>b</sup>	734.91 ± 3.60 <sup>b</sup>	0.73 ± 0.01 <sup>a</sup>
F5	6.16 ± 0.18 <sup>c</sup>	197.10 ± 3.55 <sup>c</sup>	651.91 ± 5.61 <sup>c</sup>	0.72 ± 0.01 <sup>a</sup>
F10	8.85 ± 0.45 <sup>d</sup>	202.24 ± 0.51 <sup>cd</sup>	658.19 ± 2.77 <sup>c</sup>	0.72 ± 0.01 <sup>a</sup>
F15	14.31 ± 0.11 <sup>e</sup>	212.94 ± 1.33 <sup>d</sup>	723.03 ± 2.73 <sup>b</sup>	0.71 ± 0.01 <sup>a</sup>

Notes: All data are means of two replicates; means with the same superscripts in a column are not significantly different ( $p > 0.05$ ).

APPF: African palmyra palm fruit flour; WF: 100% wheat flour; F5: 95% wheat flour:5% APPF; F10: 90% wheat flour:10% APPF; F15: 85% wheat flour:15% APPF; SP: swelling power; SI: solubility index; WAC: water absorption capacity; BD: bulk density.

100% APP fruit flour with the highest value, 4.53% and 26.48%, respectively. Both the swelling power and solubility index relatively increased with increasing substitution of APP fruit flour.

The amylopectin content of the flour is primarily responsible for granule swelling (Park & Baik, 2004) which indicates that the 100% WF and 15% APP fruit composite flour (F15) had the most amylopectin content. Also, Moorthy and Ramanujam (1986) reported that the swelling power of granules is an indication of the extent of associative forces within granule. Both flour solubility and swelling power influence the quality of noodles. In this study, as the solubility index increased, the cooking loss of noodles also increased. Swelling power is an indicator of flour starch granule characteristics including its pasting behaviour and a subsequent indicator of noodle quality (Bettge, 2003; Crosbie, 1991).

### 3.2.3. Bulk density

There was no significant difference ( $p > 0.05$ ) in the bulk density which ranged from 0.71 g/mL in the 15% APP fruit flour (F15) to 0.73 g/mL in the 100% WF (Table 3). Although not statistically significant, the bulk density decreased as the percentage of APP fruit flour in the formulation increased. Bulk density is a measure indicative of flour heaviness, type of packaging material suitable for transportation of food materials and handling requirement of food materials (Oppong et al., 2015). Flours with bulk densities in the range of 0.7–1.0 g/mL could be described as heavy highly dense flours. According to Akpata and Akubor (1999) and Kavitha and Parimalavalli (2014), flours with lower bulk densities are suitable for complementary foods and foods for convalescents. Chandra et al. (2015) explained that flours with lower bulk densities result in less viscous paste, hence their suitability for complementary foods and foods for convalescents. Therefore, the relatively high density of the APP fruit–wheat composite flours in the present study indicated that the flours could function as thickeners and thus yield pastes with high viscosities which in turn is a desired attribute of flours intended for noodle making. According to Ajani et al. (2016), the relative high bulk density of the flour blends indicated that packaging them would be economical.

### 3.3. Pasting profile of APP fruit flour, wheat flour and APP fruit–wheat composite flours

In the present study, the pasting parameters (peak viscosity, trough viscosity, breakdown viscosity, final viscosity, set back value and peak time) decreased with increasing substitution of the APP fruit flour in the composite flour (Table 4). This decrease was, however, not statistically significant ( $p > 0.05$ ) in the hot paste/trough viscosity values. There was no well-defined trend among the pasting temperature values. The peak viscosity of the WF (control) recorded the highest value and the APP fruit flour recorded the least, although there was no significant difference between the control and the 5% composite flour. The peak viscosity is an indication of the maximum viscosity during cooking or heating (Dzogbefia et al., 2008), and according to Thomas and Atwell (1999), it is usually correlated with final product quality. It was reported to correlate positively with noodle smoothness and negatively with sensory hardness of noodles (Baik et al., 2003; Baik & Lee, 2003; Seib, 2000). This implies that APP fruit flour could negatively influence the smoothness and enhance the texture of APP fruit–wheat composite flour noodles.

Trough viscosity/hot paste viscosity which measures the ability of starch to remain undisrupted when it is subjected to a long duration of high constant temperature during processing (Jimoh et al., 2009) decreased with increased concentration of the APP fruit flour. There was no significant difference among the trough viscosity values of the flours.

Breakdown viscosity ranged from 10.50 cP (APP fruit flour) to 243.00 cP (WF). It is the measure of the tendency of swollen starch granules to rupture when held at high temperatures and continuous shearing (Patindol et al., 2005). According to Olufunmilola et al. (2009), low breakdown value is an indication of greater stability under hot condition and stronger cross-linking within the flour starch granules.

**Table 4. Pasting properties of APP fruit flour, wheat flour and APP fruit–wheat composite flours**

Flour	PV (cP)	TV (cP)	BDV (cP)	FV (cP)	SV (cP)	PTemp (°C)	PTime
APPF	255.50 ± 16.26 <sup>b</sup>	245.00 ± 12.73 <sup>b</sup>	10.50 ± 3.54 <sup>a</sup>	506.50 ± 24.75 <sup>a</sup>	261.50 ± 12.02 <sup>a</sup>	55.35 ± 0.07 <sup>a</sup>	6.73 ± 0.28 <sup>b</sup>
WF	853.00 ± 0.00 <sup>a</sup>	610.00 ± 0.00 <sup>a</sup>	243.00 ± 0.00 <sup>c</sup>	1045.00 ± 0.00 <sup>b</sup>	435.00 ± 0.00 <sup>c</sup>	93.60 ± 0.00 <sup>b</sup>	6.20 ± 0.00 <sup>ab</sup>
F5	792.00 ± 15.56 <sup>a</sup>	555.50 ± 20.51 <sup>a</sup>	236.50 ± 4.95 <sup>c</sup>	948.00 ± 16.97 <sup>b</sup>	392.50 ± 3.54 <sup>bc</sup>	94.43 ± 0.11 <sup>c</sup>	6.17 ± 0.05 <sup>ab</sup>
F10	496.50 ± 53.03 <sup>b</sup>	299.00 ± 31.11 <sup>a</sup>	197.50 ± 21.92 <sup>bc</sup>	589.00 ± 60.81 <sup>a</sup>	290.00 ± 29.70 <sup>ab</sup>	64.90 ± 0.28 <sup>d</sup>	9.23 ± 0.14 <sup>c</sup>
F15	315.00 ± 1.41 <sup>b</sup>	231.50 ± 3.54 <sup>a</sup>	83.50 ± 2.12 <sup>b</sup>	428.50 ± 4.95 <sup>a</sup>	197.00 ± 1.41 <sup>a</sup>	94.50 ± 0.14 <sup>c</sup>	6.03 ± 0.14 <sup>a</sup>

Notes: All data are means of two replicates; means with the same superscripts in a column are not significantly different ( $p > 0.05$ ). APPF: African palmyra palm fruit flour; WF: 100% wheat flour; F5: 95% wheat flour; 5% APPF; F10: 90% wheat flour; 10% APPF; F15: 85% wheat flour; 15% APPF; PV: peak viscosity; TV: trough viscosity; BDV: breakdown viscosity; FV: final viscosity; SV: setback viscosity; PTemp: pasting temperature; PTime: peak time.

This indicates that APP fruit flour influenced the cross-linking within the starch granules, thereby making them less susceptible to breakdown, i.e., more resistant to heat and shear force during heating. Therefore, composite flours have a higher paste stability than the control (WF).

The final viscosity indicated the reassociation of starch granules, especially amylose during cooling time after gelatinization and the formation of gel network (Chanapamokkhot & Thongngam, 2007). The lower breakdown and final viscosity with increased levels of APP fruit flour indicated the ability of the flour to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear stress during stirring (Abioye et al., 2011; Tharise et al., 2014).

The setback value ranged from 239.50 cP to 435.00 cP with the 15% APP fruit–wheat composite flour recording the least value and the control (100% WF) recording the highest value. Sanni et al. (2006) reported that setback is the cooling phase of the mixture during pasting in which a reassociation between the starch molecules occurs to a greater or lesser degree and also lower setback viscosity indicates higher resistance to retrogradation. This implied that the APP fruit flour is suitable for retarding retrogradation, the cause of undesirable textural characteristics in starch-rich foods like bread.

The time in minutes at which peak viscosity occurred is termed peak time (Adebowale, Sanni, et al., 2005). The peak time of the composite flour in this study ranged from 6.03 to 9.23 minutes. The peak time was highest in the 10% composite flour which implies that it cooks slowly, whereas the other flours cook fast. The temperature at which the flour paste is termed as the pasting temperature. From Table 4, the 10% composite flour requires the least heat to paste.

### **3.4. Sensory evaluation for APP-fruit–wheat composite flour noodles**

Results from the sensory evaluation are shown in Table 5. Significant differences ( $p < 0.05$ ) were recorded amongst the attributes such as colour, appearance and texture, whilst the remaining attributes of the formulated noodles showed no significant differences ( $p > 0.05$ ) amongst them. The substitution of WF with APP fruit flour at 5% level increased the colour, appearance, texture, smell, flavour and overall preference scores of APP fruit–WF noodles. However, higher substitutions at 10% and 15% decreased these parameters. It could also be noticed that the increased substitution of APP fruit flour increased the consumer dislike for the aftertaste of the noodles.

#### **3.4.1. Colour**

Colour, texture and flavour are the most important sensory parameters of interest in evaluating the sensory quality of noodles (Adejunwon et al., 2019; Gulia et al., 2014). Sensory scores for the colour of the noodles ranged from 4.05 to 5.30. The panelists neither liked nor disliked the color of N3 (15% APP fruit flour noodles) which was not significantly different ( $p > 0.05$ ) from the colors of N2 (10% APP fruit flour noodles) and 100% WF noodles. However, the noodle with the most preferred color (5.30) was the 5% APP fruit flour noodle. The preference for the color decreased with increased substitution of the APP fruit flour. This indicated a deviation from the usual color of noodles generally known and accepted by panelists. Instant noodles are usually bright yellow in colour (Hou & Kruk, 1998). However, this could be altered by the nature of the raw materials used for producing the noodles. APP fruit pulp is characterized by an orange colour due to the presence of significant levels of carotenoids (Ali et al., 2010c). This attribute influenced the colour of the formulated noodles conferring a light orange shade to the final product after cooking. This confirms a previous claim that the flour color influences the color of noodles (Baik et al., 1995; Ye et al., 2009). Processing operations like steaming and drying as well as the ash content and protein quality are other factors that influence the brightness and yellowness of noodles (Park & Baik, 2004; Zhang et al., 2005). According to Morris (2018), higher ash content is associated with greater noodle discoloration. Therefore, the decrease in colour scores at higher percentages of APP fruit flour inclusions could be attributed to the increased ash content of the composite flours.

**Table 5. Sensory evaluation of APP-fruit-wheat composite flour noodles**

Formulation	Colour	Appearance	Firmness	Texture	Smell	Flavour	Aftertaste
CTRL	5.00 ± 1.45 <sup>ab</sup>	4.55 ± 1.57 <sup>ab</sup>	5.15 ± 1.34 <sup>a</sup>	4.95 ± 1.57 <sup>ab</sup>	5.30 ± 1.13 <sup>a</sup>	5.05 ± 1.36 <sup>a</sup>	5.35 ± 1.27 <sup>a</sup>
N1	5.30 ± 1.22 <sup>b</sup>	4.95 ± 0.94 <sup>a</sup>	5.05 ± 1.43 <sup>a</sup>	5.30 ± 1.45 <sup>b</sup>	5.65 ± 1.09 <sup>a</sup>	5.30 ± 1.34 <sup>a</sup>	5.20 ± 1.28 <sup>a</sup>
N2	4.30 ± 1.45 <sup>ab</sup>	4.05 ± 1.61 <sup>ab</sup>	4.60 ± 1.50 <sup>a</sup>	4.30 ± 1.45 <sup>ab</sup>	4.95 ± 1.43 <sup>a</sup>	4.50 ± 1.63 <sup>a</sup>	4.50 ± 1.70 <sup>a</sup>
N3	4.05 ± 1.64 <sup>a</sup>	3.55 ± 1.61 <sup>b</sup>	4.30 ± 1.41 <sup>a</sup>	3.75 ± 1.62 <sup>a</sup>	4.80 ± 1.61 <sup>a</sup>	4.20 ± 1.89 <sup>a</sup>	4.10 ± 2.02 <sup>a</sup>

Notes: All data are means of two replicates; means with the same superscripts in a column are not significantly different ( $p > 0.05$ ).

Control: 100% wheat flour; N<sub>1</sub>: 95% wheat flour:5% APP fruit flour; N<sub>2</sub>: 90% wheat flour:10% APP fruit flour; N<sub>3</sub>: 85% wheat flour:15% APP fruit flour). 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.

#### 3.4.2. Appearance

The panelists rated the appearance in the range 3.55 in noodles with 15% APP fruit flour (N3) to 4.95 in noodles with 5% APP fruit flour (N1). This indicated that the appearances of the control noodle (4.55) and the N1 (4.95) were liked slightly, whereas that of noodles with 15% APP fruit flour was neither liked nor disliked. According to Konik et al. (2006), flour starch quality and content influence the appearance and surface smoothness of noodles. Flours with lesser starch and/or more damaged starch granules result in noodles with excessive surface swelling (Hatcher et al., 2002).

#### 3.4.3. Texture and firmness

The texture of the noodles ranged from 3.75 to 5.30. Formulation N1 (95:5) was rated the highest and was significantly different from the remaining samples. In the work of Yamauchi et al. (2007), it was confirmed that a good noodle texture (hardness and elasticity) is associated with strong and high protein contents. The characteristics of starch are also essential in determining noodle quality as noodle texture depends greatly on gelatinized starch (Bushuk, 1998). The texture is dependent on flour quality, water absorption, ingredients used and processing operations like steaming and dehydration mechanisms (Gulia et al., 2014). According to Hou and Kruk (1998), the instant noodles with ideal textural properties are to be firm, chewy and smooth and have a good mouthfeel and a stable texture in hot water. Results obtained for the firmness of the noodles were in the range 4.30 in N3 to 5.15 in the control noodle (CTRL). There was, however, no significant differences among these values. Although there was no statistically significant difference, firmness decreased with increased levels of APP fruit flour (as shown in Table 5). This trend was similar to the findings of Yadav et al. (2014) who investigated the suitability of sweetpotato, water chestnut and colocasia flour blends with WF for noodle making. Like texture in general, flour protein content and starch properties have a positive correlation on the firmness of both cooked and uncooked noodles (Asenstorfer et al., 2010; Bushuk, 1998; Wang et al., 2004). Chompreeda et al. (1987) stated flour gluten content and strength to be the key determining factor of noodle firmness. In Table 2, the total protein content of the composite flours decreased as the level of APP fruit flour increased. Therefore, the trends for flour protein content and noodle firmness in this study were similar.

#### 3.4.4. Flavour and smell

As presented in Table 5, the flavour of APP fruit-wheat composite flour noodles ranged from 4.20 (neither like nor dislike) in the 15% APP fruit-wheat composite flour noodles (N3) to 5.30 (like slightly) in the 5% APP fruit-wheat composite flour noodles (N1). Although there was no significant difference among flavour scores, the noodles with 5% APP fruit flour recorded the highest score. A similar trend of results was obtained for the smell scores where the most preferred noodle (N1) obtained the highest smell score (5.65). This indicated the APP fruit flour imparted a desirable flavour and smell onto the noodles at a 5% level of inclusion but an undesirable flavour at higher levels of substitution probably due to its unfavorable aftertaste. The observation confirmed an earlier claim by Adzinyo et al. (2015) that the fresh APP fruit pulp is often boiled with corn or porridge to impart color and flavor. Due to the strong and unique characteristic smell of the APP fruit, it also imparts an aromatic smell when used in these foods.

#### 3.4.5. Aftertaste

The result obtained for the aftertaste of the noodles was in the range 4.10 in the 15% APP fruit-wheat composite flour noodles (N3) to 5.35 in the control (CTRL). Although no statistically significant differences existed among the recorded values, the aftertaste generally decreased from like slightly (5.35) in the control noodle to neither like nor dislike (4.10) as the level of APP fruit flour inclusion increased. This could be attributed to the slight bitter aftertaste of the APP fruit flour due to its high levels of saponins reported in an earlier study. Abe-Inge et al. (2018b) reported that the hot-air oven-dried APP fruit flour contained 36.10 g/100 g saponins.

**Table 6. Overall mean sensory score of APP fruit–wheat composite flour noodles**

Formulation	Overall mean score
Control	4.87 ± 0.91 <sup>ab</sup>
N1	5.03 ± 0.81 <sup>b</sup>
N2	4.36 ± 0.97 <sup>ab</sup>
N3	4.10 ± 1.14 <sup>a</sup>

Notes: All data are means of two replicates; means with the same superscripts in a column are not significantly different ( $p < 0.05$ ). Control: control: (100% wheat flour); N<sub>1</sub>: 95% wheat flour:5% APP fruit flour; N<sub>2</sub>: 90% wheat flour:10% APP fruit flour; N<sub>3</sub>: 85% wheat flour:15% APP fruit flour. 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.

### 3.4.6. Overall mean sensory score

The overall mean sensory score represents the average of all sensory attributes evaluated. It shows the overall sensory perception of the panellists for the APP fruit–wheat composite flour instant noodles. As shown in Table 6, the scores ranged from 4.10 in the 15% substitution (N3) to 5.03 in the 5% substitution (N1). This indicates that the 5% APP fruit flour noodle was the most preferred with regard to developing APP fruit–wheat composite flour noodles. There were no significant differences ( $p < 0.05$ ) between the control (100:0) and N2 (90:10) samples which implied the panellists preferred 5% APP fruit flour noodle (N2) just as the control noodle. The higher overall mean sensory score (5.03) for the N1 (95:5) could be due to its higher scores for all the other attributes with the exception of firmness and aftertaste.

### 3.5. Cooking properties

Table 7 shows the cooking properties of the APP fruit–wheat composite flour instant noodles. The cooking yield, water uptake and gruel solid loss ranged from 259.81% to 300.97%, 159.81% to 200.97% and 11.52% to 17.11%, respectively, where the control noodle (0% APP fruit flour:100% WF) recorded the least, whereas the 15% APP fruit flour:85% WF noodle (N3) recorded the highest for both parameters. Generally, there were significant variations ( $p < 0.05$ ) among the cooking properties for the various noodle samples.

However, the cooking yields obtained from samples (95:5) and (85:15) did not vary significantly from each other. The gruel solid loss in this study was higher than the 6.8–14.33% (Shere et al., 2018) and 6.40–7.03% (Sood et al., 2018) reported for spinach puree noodles and jamun seed powder noodles, respectively. However, they were lower than 23.80–28.30% cooking loss reported for corn flour noodles (Yalcin & Basman, 2008).

The measures of the cooking yield and gruel solid loss are important parameters to determine the cooking quality of noodles (Foo et al., 2011; Li & Vasanathan, 2003). According to Gulia et al. (2014), amylose structures in the starch granules absorb water and swell during boiling in water, leading to water uptake by cooked noodles and hence influencing cooking yields. As shown in

**Table 7. Some cooking properties of APP fruit–wheat composite flour noodles**

Noodle	Cooking yield (%)	Water uptake (%)	Gruel solid loss (%)
CTRL	259.81 ± 0.39 <sup>a</sup>	159.81 ± 0.39 <sup>a</sup>	11.52 ± 0.05 <sup>a</sup>
N1	296.63 ± 2.03 <sup>b</sup>	196.63 ± 2.03 <sup>b</sup>	13.60 ± 0.05 <sup>b</sup>
N2	272.62 ± 3.15 <sup>c</sup>	172.62 ± 3.15 <sup>c</sup>	15.06 ± 0.01 <sup>c</sup>
N3	300.97 ± 2.72 <sup>b</sup>	200.97 ± 2.72 <sup>b</sup>	17.11 ± 0.04 <sup>d</sup>

Notes: All data are means of two replicates; means with the same superscripts in a column are not significantly different ( $p > 0.05$ ).

CTRL: control (100% wheat flour); N1: (95 W:5A); N2: (90 W:10A); N3: (85 W:15A).

Tables 3 and 7, it was clear that this phenomenon is dependent on the WAC of the flours used as ingredients since both the results of the cooking yield of the noodles and water absorption capacities of the flours followed a similar trend.

Noodles of high quality have low gruel solid loss which indicates the noodles' resistance to cooking damages (Nagao, 1996). It was observed that gruel solid loss increased with higher APP fruit flour substitution. As shown in Table 3, it is clear that the gruel solid loss (cooking loss) and the solubility index followed a similar trend. This indicated that the increasing gruel solid loss could be attributed to the increase in solubility index of the composite flour as the APP fruit flour substitution increased. Similar trends were observed in the work of Shahsavani and Mostaghi (2017) on incorporating the spirulina seaweed into alkaline noodles. According to Resmini and Pagani (1983), without proper formation of gluten network during noodle preparation, poor elasticity and compactness are experienced, leading to easy swelling of starch granules during cooking and thus loss of soluble matter into the cooking water. As much as the protein content of the flours is vital in the formation of strong dough structure, excessive starch content disrupts gluten network, leading to breakages and cooking losses (Li et al., 2014).

### 3.6. Proximate composition of preferred noodle against control noodle

Table 8 displays some selected proximate composition of the most preferred noodle (95% W:5% A) against the control noodle (100% WF) in this study. At 5% significance level ( $\alpha = 0.05$ ), no significant difference existed between the ash content (0.96% and 0.94%) and moisture content (7.40% and 7.42%) of the most preferred noodle and control noodle. However, for the percentage of crude fibre and protein contents, the preferred noodle recorded significantly higher values (0.99% and 9.65%, respectively) than the control noodle (0.55% and 8.09%, respectively). The moisture levels of the noodles in this study were higher than the 5.03% and 11.09% to 14.63% reported for 100% rice and rice/orange-fleshed sweet potato composite flour pasta reported in the study by Mbaeyi-Nwaoha and Ugwu (2018). The low moisture content of the noodles indicated their potential stability against microbial spoilage since most spoilage microorganisms survive, grow and multiply at higher moisture levels (Hassan & Umar, 2004). Also, the low moisture content was an indication of the potential low cost of transportation per ton of APP-wheat composite flour noodles. The ash contents of both the control and preferred (5% APP-WF) noodles in this study were higher than the 0.89% in both 5% spirulina-WF noodles and 6% jamun seed powder-WF noodles reported by Shahsavani and Mostaghi (2017) and Sood et al. (2018), respectively. The ash content of the 5% APP-WF noodle was not only higher than the 100% WF noodle in this study but also higher than that reported by Tijani et al. (2017).

However, the ash contents of APP fruit-wheat composite flour noodles were lower than the 1.23–1.74% in breadfruit flour noodles (Tijani et al., 2017), 1.11–5.50% for selected noodles sold in Nigerian markets and 1.57–3.60% (Onyema et al., 2014) in spinach puree noodles (Shere et al., 2018). Ash is an approximate measure of the total mineral content of a material and is influenced by the nature and quantities of the ingredients in the food material as well as processing methods. The higher ash content

**Table 8. Some selected proximate composition of the most preferred noodle against the control noodle**

Parameter	Control noodle	Preferred noodle
Ash (%)	0.94 ± 0.01 <sup>a</sup>	0.96 ± 0.04 <sup>a</sup>
Moisture (%)	7.42 ± 0.74 <sup>a</sup>	7.40 ± 0.82 <sup>a</sup>
Crude fibre (%)	0.55 ± 0.02 <sup>a</sup>	0.99 ± 0.01 <sup>b</sup>
Crude protein (%)	8.09 ± 0.21 <sup>a</sup>	9.65 ± 0.15 <sup>b</sup>

Notes: All data are means of two replicates; means with the same superscripts in a row are not significantly different ( $p > 0.05$ ).

Control noodle: 100% wheat flour; preferred noodle: 95% wheat flour:5% African palmyra palm flour.

of the 5% APP-WF noodle than the 100% WF noodle could be due to the relatively higher ash content of APP fruit flour as shown in Table 2. Also, the higher ash content of the 100% WF noodle than values reported in previous studies could be due to the inclusion of sodium chloride in the flour formulation.

The most preferred noodle (5% APP-WF) recorded about 80% higher crude fibre content (0.99%) than the control (which recorded 0.55%). The crude fibre content of the preferred APP fruit flour noodle in this study was lower than the 3.55% for 5% spirulina seaweed noodles and similar to the 0.97% for 10% breadfruit noodle reported by Shahsavani and Mostaghi (2017) and Tijani et al. (2017), respectively. Also, the 5% APP fruit-wheat composite flour noodles contained higher crude fibre than cassava-wheat-soybean composite flour noodles which were reported by L. O Sanni et al. (2004) to contain between 0.4% and 0.8% crude fibre. Crude fibre content is an indication of the level of dietary fibre in a food material. Dietary fibre is an essential functional ingredient that functions as prebiotic for gut microflora; confers hypocholesterolemic, hypoglycaemic and hyperlipidaemic effects; and thus helps in preventing diabetes, obesity and cardiovascular diseases. According to Pereira (2004), dietary fibre reduces cholesterol levels by complexing with cholesterol and interfering with its absorption in the gastrointestinal tract. By functioning as a prebiotic, dietary fibre helps to maintain a healthy gut system by serving as a source of short-chain fatty acids which further serve as the major source of metabolic energy for gut bacteria (Wong et al., 2006). The increased crude fibre content in the preferred noodle due to the incorporation of APP fruit flour could help contribute to meeting the required daily dietary fibre intake.

Protein is essential in the body for the biosynthesis of hormones, enzymes and antibodies as well as for bodybuilding. The crude protein content (9.65%) of the preferred APP fruit flour noodle was significantly higher than the 8.09% of the control noodle. Although the most preferred noodle contained higher crude protein (9.65%) than the 5.8–8.4% values reported by Sanni et al. (2004) for cassava-wheat-soybean noodles, the crude protein for noodles in this study was generally lower than the 10.0–11.8% for Japanese alkaline noodles, 12.66–14.46% for spirulina seaweed noodles and 12.4–19.0% for breadfruit flour noodles reported by Crosbie et al. (1999), Shahsavani and Mostaghi (2017) and Tijani et al. (2017), respectively. The lower crude protein content of APP fruit-wheat composite flour noodles could be attributed to the lower crude protein content (3.66%) of APP fruit flour as indicated in Table 2.

#### 4. Conclusion

APP fruit flour inclusion demonstrated a significant effect on the cooking properties and sensory attributes of noodles attributed to its influence on the proximate composition and functional properties of the composite flour. APP fruit flour substitution at 5% level yielded the most preferred APP fruit-wheat composite flour noodles with the most suitable cooking properties, flavour, colour, texture, smell, appearance and overall mean score. Partially substituting WF with APP fruit flour at 5% level yielded noodles with higher crude fibre, ash, protein and enhanced appearance, texture, flavour, colour, smell and overall acceptability than the 100% WF noodles. Therefore, incorporation of APP fruit flour into noodles should be considered to maximize the utilization and reduce wastage of APP fruits.

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