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# Physicochemical, functional and sensory properties of tapioca with almond seed (*Terminalia catappa*) flour blends

**Adedola S. Adeboye[1*], Adefunke Bamgbose[1], Oluwafemi A. Adebo[2], Damaris C. Okafor[3] and Tajudeen B. Azeez[1]**

[1]Department of Food Technology, Moshood Abiola Polytechnic, Abeokuta, Ogun State, Nigeria.
[2]Department of Biotechnology and Food Technology, University of Johannesburg, South Africa.
[3]Department of Food Science and Technology, Federal University of Technology, Owerri, Nigeria.

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**The growing occurrence of malnutrition in developing countries is gradually receiving the needed research attention. Plant protein products exhibited potential for protein supplementation of tapioca and was thus explored in this study. Cassava tubers (*Manihot esculenta*) were processed into tapioca grits (partially gelatinised irregular flakes from roasted cassava starch grits) with different proportion of almond seed (*Terminalia catappa*) flour (ASF) (0 to 50% ASF w/w). The samples were evaluated for their proximate composition, energy value, functional and sensory properties. The results showed that the ASF-cassava starch grits had significantly ($p < 0.05$) higher protein, fat and ash contents but lower water absorption and swelling capacities, compared to the 100% cassava tapioca. Substitution of cassava starch with ASF significantly ($p < 0.05$) reduced the acidity and cyanide content of the tapioca but had a negative effect on the pasting properties of starch grits and sensory attributes (taste, colour and texture) of the tapioca. The study concluded that the fortification of cassava starch with ASF at 10% level has commercial potential.**

**Key words:** Cassava starch, almond seed flour, physicochemical properties, functional properties, acceptability.

## INTRODUCTION

Cassava *(Manihot esculenta* Crantz*)* is a major food crop in Nigeria, known to be highly perishable and thus often processed immediately after harvest into stable products such as tapioca (Olatunde et al., 2016). Tapioca, partially gelatinised cassava starch grits is mostly consumed as convenience food with sugar and or milk (Adebowale et al., 2007). Nutritionally, tapioca contains a substantially high amount of carbohydrate (78 to 96%) in form of starch (Samuel et al., 2012). It ranks as the 6th most important source of energy in human diets on a worldwide basis and as the 4th supplier of energy after rice, sugar and corn (Heuberger, 2005). The protein

*Corresponding author. E-mail: dola.adeboye@gmail.com.

content of tapioca is very low and may vary between 0.31 and 1.20% depending on the cassava variety (Balogun et al., 2012). Successful improvement of the nutritional value of tapioca meals using defatted soybean flour (Balogun et al., 2012), full fat soybean flour (Otegbayo et al., 2013), 'bambara' groundnut (*Vigna subterrenea*) flour (Olatunde et al., 2016), soy milk (Okafor et al., 2017) and soybean protein isolate (Villanueva et al., 2018) have been reported. The nutrient density of some underutilized fruit e.g. almond can similarly be exploited in enriching staple foods and deserts (Ezeokonkwo and Dodson, 2004).

According to Ezeokonkwo and Dodson (2004), tropical almond (*Terminalia catappa*) is one of the lesser known legumes found in the tropics. It was reported (Ezeokonkwo and Dodson, 2004) that almond seed is rich in protein (25.81%) and amino acids (isoleucine, histidine, valine, tryptophan, threonine and tyrosine). The recommended protein daily allowance for children is between 23.0 and 36.0 g and for adult 44 and 56 g (Senga et al., 2013). Ezeokonkwo and Dodson (2004) suggested that regular intake of tropical almond seed can contribute to the attainment of these recommended daily protein requirements. The seed is used by rural dwellers in the Eastern part of Nigeria to fortify local foods that are considered to be low in protein content (Mbah et al., 2013).

The use of tropical almond seed flour to fortify tapioca meal may be another of several ways to exploit the nutritional potential of tropical almond seed and enhance value addition in tapioca. A key aspect of composite flour is its functional properties; as the new ingredient may affect the behavior of the blend during processing or the sensory quality of the finished product (Otegbayo et al., 2013). Thus, the objective of this study was to enhance the functional, nutritional qualities (especially protein content) of cassava starch-almond seed flour blends.

## MATERIALS AND METHODS

Fresh weight sweet variety of cassava (*M. esculenta*) roots was obtained from DUFARMS at Federal University of Agriculture Abeokuta (FUNAAB), while tropical almond seeds were gathered within the Ibara community of Abeokuta, Ogun State, Nigeria.

### Preparation of cassava moist starch

Cassava starch and tapioca were prepared according to Samuel et al. (2012) with slight modification. The peeled cassava roots were washed with portable water to remove dirt and other earthy foreign materials. The washed roots were grated with a mechanical grater to reduce particle size and to facilitate hydrolysis of cyanogens; and the slurry obtained was then sieved to separate shaft from the starchy solution. The starch-water filtrate was allowed to stand in order for starch to settle at the base of the container and the water was decanted. The isolated starch was then air-dried overnight under room temperature on a stainless steel tray. The damp starch lumps obtained were then rubbed through a stainless steel sieve of about 20 inch mesh size into large shallow stainless steel pan. The granulated damp starch in the pan was roasted over an open firewood flame for 20 min at 120 to150°C with constant stirring. The stainless steel pan was rubbed with vegetable oil before roasting to avoid the tapioca sticking to the pan and getting burnt (Adebowale et al., 2006).

### Preparation of tropical almond seed flour (ASF)

Tropical almond flour was produced by the method reported by Ezeokonkwo and Dodson (2004). The collected tropical almond nuts were screened to remove the bad stones, debris and damaged nuts. They were then sun dried and cracked by the sharp edge of a hammer. The kernels were thus obtained intact and then dried to constant weight in a hot-air oven (40°C, 8 h). The covering of each nut was then removed by abrasion and then winnowed to expose cream colour nuts. Dried clean nuts were then milled into fine powder using laboratory hammer mill. The fine ASF flour was stored in air tight container at 4°C for further processing.

### Preparation of almond seed flour (ASF)-cassava starch composite tapioca

Almond seed flour (ASF)-tapioca flour was produced by the incorporation of ASF into the damp starch at different ratio (w/w, basis) just before roasting in the pan as described previously. The ratio was as follows: 0% ASF (100% cassava starch), 10% ASF (10% ASF+90% cassava starch), 20% ASF (20% ASF+80% cassava starch), 30% ASF (30% ASF+70% cassava starch), 40% ASF (40% ASF+60% cassava starch) and 50% ASF (50% ASF+50% cassava starch).

### Proximate composition and energy value

Moisture, ash, crude fat and crude protein contents of the tapioca samples were determined using AOAC methods (925.45B, 942.05, 920.39A and 968.06), respectively (AOAC, 2005). Total carbohydrate was calculated by difference, while the energy value was estimated using the Atwater factors [Energy value (kcal/g) = (% Protein × 4 + % Carbohydrate × 4 + % Fat × 9.0)] (FAO, 2003).

### Functional properties

#### *Sample pasting*

The pasting properties of the ASF-tapioca composite grits and that of the control sample (100% cassava starch) were determined with the use of Rapid Visco Analyser (Model 3D, Newport, Scientific Pty Ltd., Warriewood, Australia). Protocol described by Ogundele et al. (2017) was used. Suspensions of ground grits (3.0 g, db) were prepared in 25 mL deionized water. The suspension was equilibrated at 50°C for 1 min and then heated to 91°C at a uniform rate of 5°C $min^{-1}$ with constant stirring at 160 rpm. The heated slurry was held at 91°C for 7 min, before it was cooled to 50°C at 5°C $min^{-1}$ and held at this temperature for 2 min.

#### *Bulk density (BD)*

The bulk density of the tapioca grits was determined using the method reported by Irungu et al. (2018), with slight modification. Briefly, 10 g each of the ASF-cassava starch composite grits and 100% cassava starch grit was placed in 25 mL graduated cylinder and packed by gently tapping the cylinder on a bench-top 10 times. The final volume of the sample was noted and the bulk density calculated using the formula:

$$Bulk\ density = \frac{\text{weight of almond tapioca(g)}}{\text{final volume}}$$

#### *Swelling index (SI)*

The SI of the ASF-cassava starch composite grits and 100% cassava starch grit were determined according to Abu et al. (2005). Each sample (1 g, db) was dispersed in deionized water (1:10, w/v), heated in water bath (80°C, 30 min) followed by cooling to room temperature (25 ± 1°C), then centrifuged at 3000 g for 15 min. The samples were then allowed to stand for 10 min at room temperature (about 25°C) and the supernatant was decanted. The SI was calculated as the ratio of the weight of the pellet to the initial weight of sample.

#### *Water (WAC) and oil absorption (OAC) capacities*

These were determined using method 56-20 of the AACC (2000) with slight modification. Specifically, 1 g each of the ASF-cassava starch composite grits and 100% cassava starch grits was dispersed in 20 mL of deionized water or refined vegetable oil and vortexed for 5 min. The samples were centrifuged (500 *g,* 20 min, 25°C), and the supernatant was decanted. The centrifuge tubes were inverted for 5 min on a non-absorbent tissue paper and the residue was weighed. The WAC and AOC were calculated as gram of oil absorbed per gram of sample, respectively.

### Physicochemical properties

#### *pH*

pH was determined as described by Otegbayo et al. (2013). 1 g each of the sample was weighed into 10 mL of distilled water in a beaker and mixed properly. The pH of the prepared sample was read on a pH meter (model 3540, Jenway, Staffordshire, UK).

#### *Cyanide content*

The cyanide content of the starch was determined as described by Hague and Badbury (2002). In each case, 100 mL of 1 g hydrogen cyanide (HCN) equivalents/L solutions were added to 0.1 M phosphoric acid, and made up to 25 mL in a standard flask. After this, stock solution of 1 g HCN equivalents/L of potassium cyanide (KCN) and acetone cyanohydrin was prepared and added to 0.1 M phosphoric acid. 2 mL of this solution was added to 2 mL of M sulphuric acid in a test tube. The test tube containing the mixture was placed in boiling water bath, ensuring that the level of the water in the bath was above that in the test tube, and heated for 1 h. Each sample was cooled in ice with stopper loosely placed. 5 mL of 3.6 M sodium hydroxide was added and after 5 min, 1 mL of 3.6 M sodium hydroxide was added to 7 mL of 0.2 M acetate buffer at pH 5.0. Chloroamine-T (0.4 mL) was added and about 5 min later, 1.6 mL of isonicotinic acid-barbituric acid was added. The absorbance of the solution was measured after 1 h at 600 nm in a spectrophotometer (Spectronic 601, Milton Roy, USA). The amount of total cyanide content present in each sample solution was obtained by linear extrapolation to zero time of the absorbance data, using a calibration curve of standard solution of KCN.

### Hedonic evaluation of tapioca

A panel of judges (n = 20) who are familiar with tapioca was drawn from the polytechnic environment. The sensory evaluation was performed in isolated booths under white light at 25 ± 1°C. The 0%ASF and the ASF-tapioca samples were each prepared with hot water (90°C) at 1 part tapioca: 2 part water, w/v ratio, steep cooked for 15 min and excess water drained off. Cooked tapioca (without any other ingredient) was allowed to cool to room temperature and coded with 3-digit random numbers. The panelists were trained on how to handle the samples for testing for the color, taste, texture, and aroma of tapioca; and the tapioca were presented to the panelists in identical containers served in random order. The panelists were asked to mark their degree of likeness of the attributes color, taste, texture and aroma of the tapioca samples. Each attribute was evaluated on a 9-point hedonic scale, where 9 represented like extremely and 1 represented dislike extremely (Iwe, 2002).

### Statistical analysis

All experiments were conducted in triplicates and values reported as mean ± standard deviation (SD). One way analysis of variance (ANOVA) was performed on all data obtained and compared ($p < 0.05$) using Turkey's least significant difference (LSD) test. SPSS for windows version 20 (IBM CA, USA) was used for statistical analysis. Pearson's correlation analysis was also performed to examine correlations between the investigated parameters.

## RESULTS AND DISCUSSION

### Physicochemical and functional properties of tapioca grits

The results of physicochemical and functional properties of the tapioca grits are shown in Table 1. The pH of all the tapioca samples was close to neutral pH. According to Otegbayo et al. (2013), such neutrality reflects relatively flavorless and tasteless characteristics in tapioca samples. Tapioca grits with 50% ASF substitution had the least pH of 5.73 which indicated that it is slightly more acidic than other samples. The cyanide content of the ASF-fortified tapioca samples decreased with increasing level of ASF substitution with the highest being 2.82 mg/100 g in 100% cassava starch tapioca and the least being 0.77 mg/100 g in tapioca sample containing 50% ASF. Although low dose of cyanide exist naturally in many products consumed by humans, but above a critical limit, it is reported to deprive cells of oxygen thereby killing the cells. The heart, respiratory system and central nervous system of human are reported to be susceptible to cyanide poisoning at high doses (Okafor et al., 2002). Tapioca samples with 30, 40 and 50% ASF, respectively had cyanide content that were within the acceptable level of consumption since they were lower than 2.0 mg/HCN/100 g recommended for cassava products (Sanni et al., 2006). This suggested the tapioca produced from 30 to 50% ASF substitution is relatively safe for consumption. Accordingly, partial substitution of cassava starch grit with ASF prior to roasting must have contributed to this observation, as a lesser amount of cassava starch was used in the ASF-incorporated samples.

**Table 1.** Physicochemical and functional properties of tapioca samples.

| Sample | pH (%) | Cyanide content (mg/100 g) | BD (g/mL) | SC (%) | OAC (%) | WAC (%) |
|---|---|---|---|---|---|---|
| 0% ASF | 6.51 $^{a}$±0.01 | 2.82$^{a}$ ±0.02 | 0.82$^{a}$±0.02 | 9.61$^{a}$±0.03 | 70.16$^{f}$±0.03 | 83.59$^{a}$±0.05 |
| 10% ASF | 6.48 $^{b}$±0.01 | 2.74$^{a}$ ±0.03 | 0.76$^{b}$±0.01 | 9.08$^{b}$±0.03 | 70.92$^{e}$±0.02 | 82.75$^{b}$±0.02 |
| 20% ASF | 6.40 $^{c}$±0.01 | 2.25$^{b}$±0.01 | 0.73$^{c}$±0.01 | 8.42$^{c}$±0.02 | 73.76$^{d}$±0.12 | 79.47$^{c}$±0.03 |
| 30% ASF | 6.20 $^{d}$±0.01 | 1.80$^{b}$±0.09 | 0.70$^{d}$±0.01 | 7.33$^{d}$±0.03 | 75.30$^{c}$±0.04 | 76.94$^{d}$±0.02 |
| 40% ASF | 6.02 $^{e}$±0.01 | 1.90$^{b}$±0.60 | 0.67$^{e}$±0.01 | 6.62$^{e}$±0.03 | 77.94$^{b}$±0.02 | 72.15$^{e}$±0.01 |
| 50% ASF | 5.73 $^{f}$±0.01 | 0.77$^{c}$±0.04 | 0.64$^{f}$±0.01 | 5.28$^{f}$±0.02 | 81.42$^{a}$±0.15 | 69.81$^{f}$±0.04 |

Data are average (± SD) of triplicates. Means having the same latter within each column are not significantly different at p=0.05 turkey LSD.
0% ASF, 100% cassava starch; 10% ASF, 10% almond seed flour + 90% cassava starch; 20% ASF, 20% almond seed flour + 80% cassava starch; 30% ASF, 30% almond seed flour + 70% cassava starch; 40% ASF, 40% almond seed flour + 60% cassava starch; 50% ASF, 50% almond seed flour + 50% cassava starch. BD, Bulk density, SC, swelling capacity; OAC, oil absorption capacity; WAC, water absorption capacity.

The BD of tapioca samples ranged from 0.64 to 0.82 g/mL with progressive reduction in bulk density as the level of ASF increased (Table 1). Bulk density of a sample reflected its density and it underscore its packaging requirements (Yadav et al., 2012). It is a quality characteristic that depends on the interplay of many factors; particle sizes, inter particle forces, and the number of contact points (Kojima and Elliot, 2012). The increase in BD observed may be attributed to the smaller particle size of the ASF relative to that of cassava starch, leading to more free space in the composite system compared to the 100% cassava starch tapioca sample. Large free space in packaged foods constitutes large oxygen reservoir which may faster oxidation which is undesirable in this case. Low loose pack density and lower BD in substituted tapioca samples is therefore a demerit because it can result in greater oxygen transmission if the tapioca is packed as food in transit (Otegbayo et al., 2013).

Similarly, the swelling capacity (SC) of the tapioca grits ranged from 5.28 to 9.61 g/g with the 100% cassava starch tapioca having the highest value, while 50% ASF substituted sample had the least (Table 1). When starches are heated in excess water, they gelatinise. The structures are hydrated and the crystalline structures of the starch granules are disrupted due to breakage of hydrogen bond (Wang and Copeland, 2013). The exposed hydroxyl group of the starch molecules (amylose and amylopectin) gets linked to the hydrogen bonding and causes an increase in granule swelling and amylose leaching (BeMiller and Whistler, 2009). Higher swelling capacity of 100% cassava tapioca starch is therefore not far-fetched since it has higher starch content in comparison to the ASF substituted samples.

Oil absorption capacity (OAC) increased with increasing ASF level; hence the 100% cassava starch tapioca had the least value of 70.16% and tapioca from 50% ASF the highest (81.42%) (Table 1). The oil absorption capacity of a food is attributed to the trapping of oil at the polar chains of proteins (Davidov-Pardo et al., 2015). Higher protein and fat content in ASF substituted samples compared to the 100% starch samples, promoted more lipid-lipid, lipid-protein interactions for higher OAC. According to Otegbayo et al. (2013), the ability of the proteins in a food sample to trap fat is an important quality characteristic because fat acts as flavor retainers and hence increases palatability. The ASF-cassava starch tapioca samples, therefore has advantage if the grits are to be involved in some innovative deep fry processing. The WAC (that is, ability of the samples to associate with water) ranged from 69.81 to 83.59 mL/g, decreasing as the level of ASF increased (Table 1). The trend observed in the result of WAC of the samples is therefore consistent with the observation and explanation given for the trend in their swelling capacity. On equivalent weight of sample, ASF-cassava starch tapioca samples may therefore produce less volume of final product compared to the 100% cassava starch tapioca.

## Pasting properties of tapioca grits

Tapioca is essentially pasted cassava starch grits, thus the pasting properties (paste-like behavior during and after cooking) become important quality indices of tapioca. As explained earlier, gelatinization of starch influenced the swelling capacity of the samples; pasting comprises the sequential changes in viscosity before, during and after the process of gelatinisation (Wang and Copeland, 2013). The pasting properties of the ASF-cassava starch composite grits and 100% cassava starch grit are shown in Table 2. As observed, there were significant differences ($p < 0.05$) in the pasting profile of the tapioca grits indicating that ASF had significant effect on the paste-like behavior of tapioca.

The pasting temperature (PT) of ASF substituted tapioca samples were significantly ($p < 0.05$) higher than that of 0% ASF. This may be attributed to higher lipid content in the ASF substituted samples (Table 2), as high lipid content hindered heat distribution in the starch matrix (Wang and Copeland, 2013). The pasting

**Table 2.** Pasting properties of tapioca samples.

| Sample | PV (RVU) | TV (RVU) | BV (RVU) | FV (RVU) | SV (RVU) | Peak time (min) | PT (°C) |
|---|---|---|---|---|---|---|---|
| 0% ASF | $3536^{a}$±8.5 | $2143^{a}$±99.0 | $1393^{a}$±90.5 | $2938^{a}$±120.9 | $805^{a}$±7.8 | $4.6^{ab}$±0.9 | $70^{d}$±1.2 |
| 10% ASF | $2380^{b}$±41.0 | $1224^{b}$±9.2 | $1157^{b}$±31.8 | $1927^{b}$±38.9 | $703^{b}$±29.7 | $4.6^{ab}$±0.0 | $73^{c}$±0.1 |
| 20% ASF | $2032^{c}$±50.2 | $1134^{b}$±74.3 | $898^{c}$±24.0 | $1757^{c}$±43.1 | $623^{c}$±31.1 | $4.6^{ab}$±0.1 | $73^{c}$±0.0 |
| 30% ASF | $1213^{d}$±2.1 | $823^{c}$±1.4 | $390^{d}$±0.7 | $1207^{d}$±6.4 | $384^{d}$±5.0 | $4.7^{ab}$±0.0 | $76^{b}$±0.5 |
| 40% ASF | $1040^{e}$±39.6 | $770^{c}$±17.4 | $271^{e}$±7.8 | $1071^{d}$±61.5 | $301^{e}$±14.1 | $5.0^{a}$±0.1 | $77^{b}$±0.6 |
| 50% ASF | $285^{f}$±9.2 | $279^{d}$±5.7 | $6^{f}$±3.5 | $449^{e}$±7.8 | $170^{f}$±2.1 | $5.0^{a}$±0.2 | $88^{a}$±0.59 |

Data are average (± SD) of triplicates. Means having the same latter within each column are not significantly different at p=0.05 turkey LSD.
0% ASF, 100% cassava starch; 10% ASF, 10% almond seed flour + 90% cassava starch; 20% ASF, 20% almond seed flour + 80% cassava starch; 30% ASF, 30% almond seed flour + 70% cassava starch; 40% ASF, 40% almond seed flour + 60% cassava starch; 50% ASF, 50% almond seed flour + 50% cassava starch. BD, Bulk density, SC, swelling capacity; OAC, oil absorption capacity; WAC, water absorption capacity. PV, Peak viscosity; TV, trough viscosity; BV, breakdown viscosity; FV, final viscosity; SV, setback viscosity; PT, pasting temperature.

temperature of the 100% cassava starch tapioca sample (70°C) was higher than the values (63.07 to 63.60°C) reported by Adebowale et al. (2007) in their study. The difference in the data might relate to cassava varieties used or the slight difference in the pasting protocol of Adebowale et al. (2007) and this current study. The temperature at the onset of the rise in viscosity is referred to as the pasting temperature (Wang and Copeland, 2013). Pasting temperature is assumed to be the least temperature required to cook a given food sample. Thus, it can have implications on energy cost of a food process (Newport Scientific, 1998). 100% cassava starch tapioca sample and 10% ASF substituted sample would likely cook faster than other samples and thus saves cost. This may be as a result of the absorption of water by the starch which softened the grits more compared to samples with less proportion of cassava starch. According to existing theory, water entered the amorphous growth rings and at a certain degree of swelling, disruptive stress is transmitted through connecting molecules from the amorphous to the crystalline regions. Amylose molecules then began to leach out from the granules as they are disrupted under shear. The viscosity of the resulting paste increased as the shear increased, until a maximum point (peak viscosity). This corresponds to the point when the number of swollen but still intact starch granules is at the maximum. The gelatinisation temperature of most starches is reported to be between 60 and 80°C (Copeland et al., 2009). It is noteworthy that the samples in the study were heated at constant rate to 91°C due to the inclusion of ASF, which has been reported (Ezeokonkwo and Dodson, 2004; Olatidoye et al., 2011) to contain relatively high protein content.

The peak viscosity (PV) of the cassava starch-ASF blends ranged from 285 to 3536 RVU. The PV decreased as the level of ASF increased. The maximum viscosity attained by gelatinised starch during heating is termed peak viscosity. As mentioned earlier, absorption of water and swelling depends on the amount of starch available. Substitution of cassava starch with ASF, therefore lowers quality of tapioca in terms of viscosity and volume. The difference between the minimum viscosity and the peak viscosity is referred to as the breakdown viscosity. BV value indicated the ability of paste to withstand heating and shear stress that is usually encountered during processing (Newport Scientific, 1998). The BV of the tapioca samples ranged between 5.5 and 1393 RVU with the value decreasing with increasing level of ASF (Table 2). Maziya-Dixon et al. (2007) explained that during the mechanical shear stress at the holding time of pasting test (in this case 91°C for 7 min), starch granules are further disrupted, amylose molecules leach into solution and align in the direction of shear. The trend observed, therefore, relates to the amount of starch available and therefore the extent of gelatinisation, amylose leaching, and alignment in the direction of shear that has occurred. A low BV value might be seen as an advantage as it suggests relative stability of starches under heat processing. However, lower BV of the ASF substituted samples is not necessarily an indication of the stability of their paste during processing; rather the system becomes less dependent on the shear force used as the starch level in the composite tapioca decreased.

When gelatinised starch is cooled, the disrupted amylose and amylopectin chains can gradually re-associate into different ordered-structure in a process termed retrogradation (Wang and Copeland, 2013) indicated by the set back section of a typical pasting curve. The setback viscosity (SV) of the tapioca samples ranged between 169 and 804 RVU (Table 2). Higher SV observed in samples with higher cassava starch level is therefore understandable. Starch retrogradation is usually accompanied by increased viscosity and turbidity of paste (Hoover et al., 2010). Higher SV (retrogradation) in samples with higher amount of cassava starch may have implication on digestibility of the tapioca as explained elsewhere (Chung et al., 2006). The 100% cassava starch tapioca recorded the highest value of final viscosity (2937.5 RVU) and was observed to have formed a firmer gel than the 50% ASF substituted sample which had the lowest final viscosity of 448.5 RVU (Table 2). The

**Table 3.** Proximate composition of tapioca sample.

| Sample | Moisture (%) | Ash (%) | Crude fibre (%) | Fat (%) | Protein (%) | Carbohydrate (%) | Energy* (kcal/g) |
|---|---|---|---|---|---|---|---|
| 0% ASF | $7.44^{f}$±0.02 | $0.99^{e}$±0.03 | $2.66^{a}$±0.02 | $0.4^{f}$±0.02 | $1.91^{f}$± 0.04 | 86.59 $^{a}$± 0.07 | $357.60^{f}$ |
| 10% ASF | $7.52^{e}$±0.02 | $1.03^{e}$±0.02 | $2.51^{b}$±0.01 | $0.67^{e}$±0.03 | $2.03^{e}$± 0.03 | 86.26 $^{ab}$± 0.07 | $359.19^{e}$ |
| 20% ASF | $7.86^{d}$±0.02 | $1.15^{d}$±0.02 | $2.34^{d}$±0.02 | $3.54^{d}$±0.09 | $2.95^{d}$±0.01 | 82.17 $^{c}$± 0.10 | $372.34^{d}$ |
| 30% ASF | $7.94^{c}$±0.02 | $1.21^{c}$±0.02 | $2.46^{c}$±0.01 | $5.33^{c}$±0.05 | $4.77^{c}$±0.01 | 78.28 $^{d}$± 0.06 | $380.17^{c}$ |
| 40% ASF | $8.36^{b}$±0.03 | $1.35^{b}$±0.01 | $2.18^{e}$±0.03 | $7.22^{b}$±0.04 | $6.24^{b}$±0.02 | 74.66 $^{e}$± 0.03 | $388.58^{b}$ |
| 50% ASF | $8.72^{a}$±0.08 | $1.79^{a}$±0.04 | $2.09^{f}$±0.04 | $8.44^{a}$±0.06 | $7.71^{a}$±0.07 | 71.25 $^{f}$± 0.16 | $391.80^{a}$ |

*At water conversion and cumulative of mean values of protein, carbohydrate and fat only. Data are average (± SD) of triplicates. Means having the same latter within each column are not significantly different at p=0.05 turkey LSD. 0% ASF, 100% cassava starch; 10% ASF, 10% almond seed flour + 90% cassava starch; 20% ASF, 20% almond seed flour + 80% cassava starch; 30% ASF, 30% almond seed flour + 70% cassava starch; 40% ASF, 40% almond seed flour + 60% cassava starch; 50% ASF, 50% almond seed flour + 50% cassava starch.

final viscosity gave an apparent indication of the ability of a material to gel after cooking, which was an appealing physical characteristic of tapioca.

## Proximate composition of tapioca samples

The results of proximate composition of the tapioca samples prepared from 100% cassava starch and blends of ASF-cassava starch are shown in Table 3. There was increased in moisture content of the tapioca samples as the level of ASF increased. However, all the tapioca samples had moisture content below 10% and as such can relatively resist microbial growth and hence have relatively high storage stability. The ash content of the tapioca grits ranged from 0.99 to 1.79%, with 100% cassava starch having the lowest ash content which suggested poor mineral availability. The ash content increased with increasing content of ASF and thus 50% ASF-tapioca samples had the highest (1.79%) ash content among all the tapioca samples. Crude fibre of the composite tapioca samples were lower than that of the 0%ASF tapioca (2.66%), indicating that ASF apparently has lower crude fibre content than cassava starch. Olatidoye et al. (2011) and Samuel et al. (2012) in their independent studies reported a crude fibre content of 0.4% in ASF and 0.7% in cassava starch, respectively. The fat content of the tapioca grits varied significantly ($p < 0.05$) ranging from 0.41 (0% ASF) to 8.44% (50% ASF). The increasing fat content in the blends as the level of ASF increased suggest that ASF contains a high fat content. Mbah et al. (2013) reported a fat content of about 22% in ASF; whereas a fat content of 0.2% was reported for 100% cassava starch tapioca in a similar substitution study (Samuel et al., 2012). Protein content of the tapioca grits varied between 1.91 and 7.71% with progressive increase as the level of ASF substitution increased. The highest energy values of 391.8 kcal/g were equally obtained at this substitution level, indicating the potential of this composite to contribute to protein and energy requirements. Previous studies similarly reported improvement in the protein content of tapioca meal fortified with full fat (Balogun et al., 2012) or defatted soybean flour (Samuel et al., 2012). Crude protein content of 32.6% was reported for ASF (Olatidoye et al., 2011). The carbohydrate content of the ASF containing tapioca samples was lower than that of 0% ASF as expected. The 10% ASF tapioca sample was however not significantly different ($p < 0.05$) from the 0% ASF tapioca.

## Sensory properties of tapioca samples

There were significant differences ($p < 0.05$) in all the sensory attributes measured except in aroma. In general, tapioca meals fortified with ASF had lower ratings compared to the control sample (Table 4). Tapioca is conventionally accepted to be white in sensory quality of color, hence the low rating recorded for the color of the ASF-supplemented samples apparently influenced sensory rating of their other attributes. Nonetheless, tapioca meal fortified with 10% ASF compared closely with the control (100% cassava starch) sample in color, taste and texture. The poor color rating of the ASF-cassava starch tapioca is due to the opacity of the composite grit emanating from the off-white color of ASF; their texture was equally rated as poor probably because of smaller particle size and poor past-like feel of the composite product. From the result, it does appear that 100% cassava starch tapioca sample was not significantly better than the sample containing 10% ASF in terms of taste; while all the ASF samples were not significantly different to the 100% cassava starch tapioca in aroma.

Functional properties (BD, SI, WAC, PV) of the sample grits had high positive correlation ($p < 0.05$), with the sensory attributes (Table 5). This is an indication that these functional properties as affected by the inclusion of ASF have profound influence on the sensory attributes of the tapioca produced. According to Mbah et al. (2013), roasting increased the availability of protein, at and

**Table 4.** Means sensory scores of tapioca samples.

| Sample | Colour | Texture | Aroma | Taste |
|---|---|---|---|---|
| 0%ASF | $8.80^{a}$±0.52 | $8.30^{a}$±1.08 | $6.60^{a}$±2.28 | $7.60^{a}$±0.94 |
| 10%ASF | $7.45^{b}$±0.76 | $7.00^{b}$±1.81 | $6.40^{ab}$±1.85 | $6.95^{ab}$±0.95 |
| 20%ASF | $6.15^{c}$±1.59 | $5.85^{c}$±1.39 | $6.70^{a}$±1.03 | $6.25^{bc}$±1.11 |
| 30%ASF | $5.5^{c}$±1.70 | $5.75^{c}$±1.91 | $5.75^{ab}$±0.97 | $5.45^{cd}$±1.57 |
| 40%ASF | $4.40^{d}$±1.31 | $4.20^{d}$±1.82 | $6.10^{a}$±1.65 | $4.75^{de}$±2.25 |
| 50%ASF | $2.00^{e}$±1.52 | $2.60^{e}$±2.04 | $6.10^{a}$±2.79 | $4.25^{e}$±2.81 |

Data are average (± SD) of triplicates. Means having the same latter within each column are not significantly different at p=0.05 turkey LSD. 0% ASF, 100% cassava starch; 10% ASF, 10% almond seed flour + 90% cassava starch; 20% ASF, 20% almond seed flour + 80% cassava starch; 30% ASF, 30% almond seed flour + 70% cassava starch; 40% ASF, 40% almond seed flour + 60% cassava starch; 50% ASF, 50% almond seed flour + 50% cassava starch.

**Table 5.** Correlation matrix of measured properties of ASF-cassava starch grits*.

| Variable | Ash | CF | Fat | CP | CHO | BD | SI | OAC | WAC | PV | BV | FV | SB | PT | Color | Texture | Aroma | Taste |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash | 1 | -0.887 | 0.895 | 0.939 | -0.928 | -0.876 | -0.954 | 0.962 | -0.927 | -0.874 | -0.883 | -0.871 | -0.902 | 0.985 | -0.963 | -0.948 | -0.469 | -0.895 |
| CF | -0.887 | 1 | -0.910 | -0.888 | 0.906 | 0.932 | 0.908 | -0.935 | 0.933 | 0.894 | 0.872 | 0.895 | 0.876 | -0.837 | 0.945 | 0.975 | 0.352 | 0.922 |
| Fat | 0.895 | -0.910 | 1 | 0.979 | -0.994 | -0.962 | -0.978 | 0.982 | -0.989 | -0.947 | -0.984 | -0.927 | -0.982 | 0.848 | -0.960 | -0.956 | -0.641 | -0.990 |
| CP | 0.939 | -0.888 | 0.979 | 1 | -0.995 | -0.937 | -0.992 | 0.987 | -0.992 | -0.929 | -0.972 | -0.912 | -0.985 | 0.908 | -0.962 | -0.951 | -0.663 | -0.975 |
| CHO | -0.928 | 0.906 | -0.994 | -0.995 | 1 | 0.954 | 0.991 | -0.992 | 0.995 | 0.943 | 0.982 | 0.924 | 0.987 | -0.888 | 0.969 | 0.961 | 0.646 | 0.987 |
| BD | -0.876 | 0.932 | -0.962 | -0.937 | 0.954 | 1 | 0.965 | -0.957 | 0.955 | 0.994 | 0.977 | 0.990 | 0.971 | -0.861 | 0.972 | 0.973 | 0.648 | 0.988 |
| SI | -0.954 | 0.908 | -0.978 | -0.992 | 0.991 | 0.965 | 1 | -0.994 | 0.987 | 0.962 | 0.982 | 0.951 | 0.990 | -0.934 | 0.987 | 0.974 | 0.656 | 0.985 |
| OAC | 0.962 | -0.935 | 0.982 | 0.987 | -0.992 | -0.957 | -0.994 | 1 | -0.991 | -0.944 | -0.966 | -0.932 | -0.974 | 0.927 | -0.989 | -0.983 | -0.576 | -0.979 |
| WAC | -0.927 | 0.933 | -0.989 | -0.992 | 0.995 | 0.955 | 0.987 | -0.991 | 1 | 0.936 | 0.970 | 0.920 | 0.979 | -0.883 | 0.969 | 0.970 | 0.605 | 0.985 |
| PV | -0.874 | 0.894 | -0.947 | -0.929 | 0.943 | 0.994 | 0.962 | -0.944 | 0.936 | 1 | 0.979 | 0.998 | 0.972 | -0.876 | 0.967 | 0.957 | 0.702 | 0.979 |
| BD | -0.883 | 0.872 | -0.984 | -0.972 | 0.982 | 0.977 | 0.982 | -0.966 | 0.970 | 0.979 | 1 | 0.963 | 0.997 | -0.864 | 0.959 | 0.944 | 0.744 | 0.993 |
| FV | -0.871 | 0.895 | -0.927 | -0.912 | 0.924 | 0.990 | 0.951 | -0.932 | 0.920 | 0.998 | 0.963 | 1 | 0.958 | -0.880 | 0.964 | 0.955 | 0.681 | 0.966 |
| SB | -0.902 | 0.876 | -0.982 | -0.985 | 0.987 | 0.971 | 0.990 | -0.974 | 0.979 | 0.972 | 0.997 | 0.958 | 1 | -0.885 | 0.963 | 0.949 | 0.741 | 0.992 |
| PT | 0.985 | -0.837 | 0.848 | 0.908 | -0.888 | -0.861 | -0.934 | 0.927 | -0.883 | -0.876 | -0.864 | -0.880 | -0.885 | 1 | -0.946 | -0.920 | -0.521 | -0.866 |
| Color | -0.963 | 0.945 | -0.960 | -0.962 | 0.969 | 0.972 | 0.987 | -0.989 | 0.969 | 0.967 | 0.959 | 0.964 | 0.963 | -0.946 | 1 | 0.994 | 0.564 | 0.973 |
| Texture | -0.948 | 0.975 | -0.956 | -0.951 | 0.961 | 0.973 | 0.974 | -0.983 | 0.970 | 0.957 | 0.944 | 0.955 | 0.949 | -0.920 | 0.994 | 1 | 0.508 | 0.970 |
| Aroma | -0.469 | 0.352 | -0.641 | -0.663 | 0.646 | 0.648 | 0.656 | -0.576 | 0.605 | 0.702 | 0.744 | 0.681 | 0.741 | -0.521 | 0.564 | 0.508 | 1 | 0.675 |
| Taste | -0.895 | 0.922 | -0.990 | -0.975 | 0.987 | 0.988 | 0.985 | -0.979 | 0.985 | 0.979 | 0.993 | 0.966 | 0.992 | -0.866 | 0.973 | 0.970 | 0.675 | 1 |

CF, Crude fibre; CP, crude protein; CHO, carbohydrate by difference; BLD, bulk density; SI, swelling index; OAC, oil absorption capacity; WAC, water absorption capacity; PV, peak viscosity; BV, breakdown viscosity; FV, final viscosity; SB, setback viscosity; PT, pasting temperature. Values in bold are different from 0 with a significance level alpha=0.05. *Extracted from principal component analysis (PCA).

crude fibre in an almond seed. Perhaps a more significant improvement in the nutritional status and or functionality of the tapioca blends would be obtained; if the almond seeds used in this study were roasted prior to incorporation into the cassava grits.

## Conclusion

The inclusion of almond seed flour into cassava starch improves the nutrient composition in terms of protein, fat, ash and energy values but decreases desirable pasting properties of the composite flour. In general, increase in the level of substitution with almond seed flour decreases water absorption, swelling capacity and bulk density of the tapioca (cassava starch) grits. Although the substitution of cassava starch with almond seed flour above 10% compromises functional and sensory properties significantly, substitution at > 10% level has significant merit from a nutrition point of view. Further study is needed to understand the effect of incorporation of both roasted and unroasted almond seed flour and possible optimization of the process on improvement in nutritional status, functionality and sensory attributes of tapioca.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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