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Influence of Roasting on the Proximate, Functional and Sensory Properties of Jackfruit Seeds and Amaranth Grain Composite Complementary Flours

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Abstract

This study evaluated the effects of roasting on jackfruit seeds (JFS) and amaranth grain composite complementary flours. Eleven formulations were used for the study. The moisture, crude protein, crude fat, crude fibre, crude ash and carbohydrate contents varied from 6.5 to 8.7%, 10.66 to 20.9%, 0.93 to 5.98%, 4.46 to 10.2%, 2.6 to 3.76% and 51.3 to 71.7%, respectively. The water absorption capacity (WAC), water solubility index (WSI), oil absorption capacity, swelling power (SP) and bulk density (BD) ranged from 238.9 to 360.5%, 3.9 to 12%, 107.4 to 200.6%, 13.3 to 45.9%, and 0.5 to 0.7 g/mL, respectively. Increasing amaranth flour and roasting JFS increased the WSI and SP but decreased the WAC and BD. The peak viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature varied from 326.5 to 1292 RVU, 15 to 417 RVU, 432 to 1334.5 RVU, 138.5 to 4595 RVU, 4.09 to 7 minutes and 79 to 90.1 °C, respectively. Viscosity of the flours increased with increase in grain amaranth. The porridges made with roasted JFS yielded higher sensory scorers, hence suitable for complementary feeding.

Keywords: Jackfruit seeds; Amaranth; Composite flour.

Introduction

Complementary foods should be introduced to children aged 6 to 24 months at the appropriate time for both nutritional and developmental reasons (Agostoni et al. 2008). However, the ability of a supplemental diet to meet these children's protein-energy needs is determined by its nutritional quality (Kamchan et al. 2004). It is generally known that in many regions of the developing world, the expense of fortified supplemental foods is out of reach for most families. Many families rely on low-nutrient staple crops as supplementary nourishment for their children (Muhimbula et al. 2011). That has led to increase in the prevalence of protein-energy malnutrition (PEM) which has become a major problem in children in developing countries (World Health Organisation 2010). There is therefore need to explore other food materials that are inexpensive and have potential to provide required nutrients for this age group. The search for lesser known and underutilized crops, many of which are potentially valuable as human foods has been the focus for research in recent years (Chivenge et al. 2015).

Jackfruit (*Artocarpus heterophyllus* Lam) seeds are low-cost indigenous and underutilized components of a widely consumed fruit that can be processed and used to make nutrient-dense complementary flours, especially when combined with a low-cost legume like amaranth grain (*Amaranthus cruentus*) (Okoth et al. 2017). The resulting combination has the potential to help alleviate protein-energy deficiency and improve children's nutrition (Muhimbula et al. 2011). The jackfruit tree (*Artocapus heterophyllus*) is a member of the Moraceae family. Per kg-wet weight of ripe perianth, the fruit provides roughly 2 MJ of calories (Ranasinghe et al. 2019). After eating the fruits, the jackfruit seeds (JFS) are normally discarded. These seeds, on the other hand, might be boiled, roasted, and eaten, or dried and milled into flour and used alone or in combination with wheat flour for baking or other raw materials such as legumes for various food applications (Morton 1987, Ranasinghe et al. 2019). Protein, fats, and carbohydrates (6.6%, 0.4% and 38%, respectively) have been observed to be quite good sources of energy nutrients in JFS (Ranasinghe et al. 2019). Phosphorus, iron, zinc, copper, and manganese, among other micronutrients, are available in JFS.

On the other side, Amaranth grain (AG) is a protein (13.04%), lipid (7.29%), carbohydrate (63.4%), and fibre (7.01%)-rich legume (*Amaranthus cruentus*) (Muyonga et al. 2008). In addition, the grain has a good amino acid profile, as well as considerable levels of iron, calcium and vitamins A, B, E, and C (Muyonga et al. 2008, Tanimola et al. 2016). Amaranth grains can be popped and eaten as snacks or milled into flour for use in a variety of recipes due to their high nutritional values. The functional properties, nutritional composition, and general acceptability of complementary foods are all affected by a variety of factors, including diversity and processing techniques, which have the potential to affect their functional properties, nutritional composition, and general acceptability (Chandra et al. 2015). The viscosity of the resulting paste is affected by functional properties such as bulk density, swelling power, and water absorption capacity; this affects the energy density (energy per unit volume) and consistency of the meal given to the infant, which is an important consideration in meeting the nutritional requirements of children (Kikafunda et al. 1997).

In some parts of Uganda, jackfruit trees are grown on a large scale (on average 0.3 million metric tonnes per year), and jackfruit is consumed by a large population (Balamaze et al. 2019). The seeds taken from these fruits, on the other hand, are discarded as garbage and are rarely consumed in any manner. The composition and functional properties of jackfruit perianth and seeds from diverse parts of the world have been documented (Odoemelam 2005). In Uganda, there is little information on the nutrient content, functional characteristics, and sensory aspects of JFS. In Uganda, there is no information on the processing of JFS into flours for use in complementary foods or other food products. The nutritional value and related properties of JFS should therefore be assessed as well as the effects of processing procedures on these properties when JFS flour is blended with amaranth grain flour. The goal of this research was to explore the effect of roasting on the proximate, sensory, and functional properties of jackfruit seed-amaranth composite flour.

Materials and Methods

Study materials

The jackfruits seeds were obtained from fresh fruits. These fruits and the dry amaranth grains were purchased from Kalerwe market in Kampala Metropolitan area in January, 2021.

Preparation of raw and roasted jackfruit seed flour

The JFS flour was obtained using the method documented by Ocloo et al. (2010). The jackfruit seeds were extracted from the perianths of fruits. The JFS were thoroughly washed with running water to remove any components of the fruits. The outer layers of the seeds were manually removed and seeds sliced with a knife. The seeds were dried for 24 hours at 70 °C to obtain moisture content of 8–10%. The dried seeds were milled to pass through a 240 µm sieve. The samples were packaged in high density polyethylene bags and kept in a cool dry place for further use. These were labelled as 'raw samples'. For the roasted samples, the previously washed seeds were roasted a 160 °C for one hour in an oven. The outer layers of the seeds were also manually removed and seeds sliced with a knife. These were labelled as 'roasted samples'.

Preparation of amaranth grain flour

Grains of *Amaranthus cruentus* variety purchased from the local market by a random method were carefully sorted and thoroughly cleaned to remove any dirt. The grains were milled with an attrition mill to obtain flour fraction of <500 µm. These products were then packed in sealed plastic bags, labelled AF and stored at 4 °C until further analysis.

Preparation of composite flours

The jack fruit seed and grain amaranth flours were blended in the following proportions: 100:0, 75:25, 60:40, 33:67, and 0:100 using Nutri-survey software. The flours were expected to provide about 10–11% protein based on the Recommended Dietary Allowances (RDAs). The above formulations were used for both raw and roasted samples, resulting into 11 study samples as indicated: F1 = 100% raw jackfruit seed flour (JFSF) and 0% amaranth grain flour (AGF), F2 = 75% raw JFSF and 25% AGF, F3 = 60% raw JFSF and 40% AGF, F4 = 50% raw JFSF and 50% AGF, F5 = 33% raw JFSF and 67% AGF, F6 = 100% roasted JFSF and 0% AGF, F7 = 75% roasted JFSF and 25% AGF, F8 = 60% roasted JFSF and 40% AGF, F9 = 50% roasted JFSF and 50% AGF, F10 = 33% roasted JFSF and 67% AGF, F11 = 0% JFSF and 100% AGA.

Analyses

Proximate composition

The following proximate components were determined in triplicate using standard methods of AOAC (1990): moisture (method 14.004), crude fat, crude ash (method 14.006), crude protein (Kjeldahl method, conversion factor N x 5.7) and crude fibre (method 7.065). The carbohydrate content was determined by difference method. The energy (caloric value) estimation was done by summing the multiplied values for crude protein, fats and carbohydrates by their respective AT WATER factors: 4, 9 and 4, respectively (Ocloo et al. 2010).

Functional properties

Water and oil absorption capacities: The water absorption capacity of the flours was determined using the method by Niba et al. (2001). Approximately 1 g of the sample was mixed with 10 mL of distilled water or refined vegetable oil in a 25 mL centrifuge tube. The slurry was agitated on a vortex mixer for 2 minutes then allowed to stand at 28 °C for 30 minutes. The slurry was centrifuged at 3000 rpm for 10 minutes and the clear supernatant was decanted and discarded. The percentage of the water or oil absorbed by 1 g of flour was considered as the water or absorption capacity.

Water Solubility Index (WSI): The Anderson (1969) method was used to determine the water solubility index of the flours. One gram of the sample was vortex mixed with 10 mL of distilled water then centrifuged at 3000 rpm for 10 minutes. The supernatant was dried in an oven at 105 °C. The water solubility index was calculated as the percentage of dissolved flour.

Swelling power: This was determined with the method described by Leach et al. (1959) with modification for small samples. One gram of the sample was mixed with 10 mL distilled water in a centrifuge tube and heated at 80 °C for 30 min. The mixture was continually shaken during the heating period. After heating, the suspension was centrifuged at 1000 x g for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling power was calculated as percentage of the fraction of the weight of the paste and weight of dry sample.

Bulk density: The bulk density was determined using the method by Narayana and Narasinga (1984). Graduated cylinder tubes (100 mL capacity) were weighed and the flour sample filled to 5 mL by constant tapping until there was no further change in volume. The contents were weighed and the difference in weight determined. The bulk density was computed as grams per milliliter of the sample.

Pasting properties: The Rapid Viscosity Analyzer method (Shittu et al. 2007) was used to determine the pasting properties of flours. About 3 g of a sample were added to 25 mL of distilled water. A programmed heating and cooling cycle at a constant shear rate was subjected to the mixture. The slurry was held at 50 °C for 1 minute and heated to 95 °C for 2 minutes, then held at 95 °C for 5 minutes. It was then cooled to 50 °C in 8.5 minutes; held at 50 °C for 2 minutes. The rotation was maintained at 160 rpm.

Sensory characteristics and overall acceptance: The sensory attributes and overall acceptance of porridges prepared from the powders different blends were evaluated by a panel of 30 un-trained panellists, selected from the staff and students of the school. The panellists carried out a multiple comparison test which was a difference analysis test between the flour blends. The porridges were prepared by mixing flour (10%) in water and adding to boiling water and stirring the mixture continuously to avoid lumping. The pastes were allowed to boil for 15 minutes, after which the different porridges were individually presented to each panellist in small disposable dishes blind-coded with 3-digit random numbers. Panellists were instructed to eat crackers and drink bottled water, as palate cleansers, and pause for 30 seconds between samples. Panellists were asked to evaluate the overall acceptability with regard to colour, flavour, aroma, and taste. The evaluation was based on a 9-point hedonic scale, where 9 (like extremely) was the highest and 1 (dislike extremely) was the lowest score. Thus, 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely.

Statistical analysis

Analysis of variance (ANOVA) was performed to determine significant differences between the means of proximate composition, functional, sensory attributes, and pasting properties using the Statistical Package for Social Sciences (SPSS) version 16.0 and Statistical Analysis System (SAS) University edition. The means were separated using the Tukey multiple comparisons test at alpha level of 0.05.

Results and Discussions

Effects of roasting on proximate composition of jackfruit seeds and amaranth grain complementary flours

Moisture content (MC): The moisture content of the study samples ranged from 6.5% to 8.7% (Table 1). The moisture content was highest in sample F11 *(J_0A_{100})*, plain amaranth and lowest in sample F7 *($Jr_{75}A_{25}$)*, with 75% roasted JFSF. There were significant differences ($p < 0.05$) in the mean moisture content among the blends. Moisture content increased with increase in amaranth proportions (Table 1). This could be due to the high protein content (14%) in Amaranth grains which are known to have stronger protein water holding capacity (Heywood et al. 2002). Moisture content was lower in formulations which contained roasted JFSF than those with raw JFSF. This could be attributable to the high temperature (160 °C for 1 hour) used during the roasting which removed most of the water from the seeds. According to Temple et al. (1996), the moisture content in weaning flour should be between 5% and 10% which was in agreement with the results obtained in this study.

Total ash (TA): The total ash content ranged from 2.6% to 3.8% (Table 1). The total ash content was highest in F6 ($Jr_{100}A_0$), with highest percentage of roasted JFSF and lowest in sample F1 ($J_{100}A_0$), with the highest proportion of raw JFSF. Roasting of JFS significantly increased the total ash content of the flours. The results showed that plain amaranth grain flour (F11) had more ash content than raw JFSF (F1), but roasting of JFS increased their ash content beyond that of amaranth grain flour. The increase in ash content could be attributed to the low moisture content observed in roasted JFSF.

Table 1: Chemical composition of the raw jackfruit seed kernel flour blends

Formulation	Proximate content (%)						Calories/100 g**
	Moisture	Ash	Crude protein	Crude fat	Crude fibre	CH_2O^*	
F1	7.8 ± 0.2^{bcd}	2.6 ± 0.1^{ab}	10.1 ± 0.1^{a}	0.9 ± 0.1^{a}	6.4 ± 0.1^{bc}	71.7 ± 4.4^{d}	319.8 ± 1.2^{a}
F2	8.6 ± 0.1^{cde}	2.8 ± 0.0^{a}	10.7 ± 0.1^{b}	2.1 ± 0.0^{ab}	5.9 ± 0.1^{a}	70.6 ± 0.2^{cd}	323.4 ± 0.4^{abc}
F3	8.8 ± 0.4^{de}	2.9 ± 0.1^{a}	10.9 ± 0.0^{ab}	2.2 ± 0.0^{cd}	5.6 ± 0.0^{a}	69.6 ± 1.5^{cd}	324.3 ± 1.6^{abcd}
F4	9.1 ± 0.0^{ef}	3.0 ± 0.1^{ab}	13.0 ± 0.0^{bc}	2.7 ± 0.1^{cd}	5.4 ± 0.0^{a}	66.8 ± 3.0^{cd}	326.3 ± 0.5^{abcd}
F5	9.5 ± 0.4^{ef}	3.2 ± 0.1^{ab}	13.1 ± 0.5^{cd}	3.3 ± 0.2^{bc}	5.1 ± 0.0^{a}	65.8 ± 0.2^{cd}	328.8 ± 1.2^{abc}
F6	7.7 ± 0.2^{abc}	3.8 ± 0.1^{c}	20.9 ± 0.3^{g}	6.0 ± 0.1^{e}	10.6 ± 0.2^{d}	51.3 ± 0.3^{a}	329.8 ± 3.5^{ab}
F7	6.5 ± 0.7^{a}	3.7 ± 0.0^{abc}	20.4 ± 0.6^{f}	5.6 ± 0.1^{h}	9.1 ± 0.2^{bc}	54.8 ± 0.0^{a}	337.0 ± 1.9^{e}
F8	7.0 ± 0.0^{ab}	3.4 ± 0.1^{bc}	19.2 ± 0.0^{ef}	5.3 ± 0.0^{cd}	8.2 ± 0.2^{bc}	57.0 ± 0.2^{a}	337.7 ± 1.0^{de}
F9	7.1 ± 0.9 ^{ef}	3.3 ± 0.1^{abc}	18.0 ± 0.2^{f}	5.1 ± 0.0^{cd}	7.5 ± 0.2^{b}	58.9 ± 0.3^{ab}	338.9 ± 0.0^{bcde}
F10	7.07 ± 0.56^{ab}	3.1 ± 0.0^{ab}	16.8 ± 0.0^{e}	4.8 ± 0.0^{bc}	6.6 ± 0.3^{bc}	60.9 ± 1.0^{ab}	338.9 ± 3.8^{abc}
F11	8.7 ± 0.1^{cde}	3.6 ± 0.2^{abc}	14.0 ± 0.2^{d}	4.3 ± 0.0^{ed}	4.4 ± 0.1^{a}	69.4 ± 6.2^{bc}	355.0 ± 22.1^{abc}

Values are means ± SD, (n = 3). Means in the same column with different superscripts are significantly different ($p < 0.05$). * Results obtained by difference, **Results obtained by calculation. Key: F1 = $J_{100}A_0$, F2 = $J_{75}A_{25}$, F3 = $J_{60}A_{40}$, F4 = $J_{50}A_{50}$, F5 = $J_{33}A_{67}$, F6 = $Jr_{100}A_0$, F7 = $Jr_{75}A_{25}$, F8 = $Jr_{60}A_{40}$, F9 = $Jr_{50}A_{50}$, F10 = $Jr_{33}A_{67}$, F11 = J_0A_{100}, CH_2O^* = carbohydrate, J is raw JFSF, A is GAF and Jr is roasted JFSF.

The general observation was that the ash content increased with the decrease in raw jackfruit seed flour but increased with increase in roasted JFSF. The results are in agreement with those reported by Morton (1987) and Maskey et al. (2020). However, the results are below the recommended levels by WHO (5%) for weaning foods.

Crude protein (CP): The crude protein content of the samples in this study ranged from 10.1% to 20.9%. F1 *($J_{100}A_0$)*, which was plain raw JFSF had the lowest and F6 *($Jr_{100}A_0$)*, which was plain roasted JFSF had the highest crude protein content (Table 1). This could have been due to concentration effects resulting from moisture loss during roasting. The results for plain JFS were in higher than those reported by Eke-Ejiofor et al. (2014) who reported 12.3% and 16.8% in autoclaved and roasted JFSF, respectively. There were significant differences ($p < 0.05$) in the CP content of the formulations. Increasing amaranth grain content significantly increased the CP content in blends with raw JFSF, but significantly decreased the CP content of formulations containing roasted JFSF. In general, roasted JFSF formulations had a greater CP than raw JFS formulations. The CP content of plain amaranth grain flour was higher than raw JFSF, and it was also found to increase the CP content of formulations in general. However, the decrease in CP values as the composition of amaranth grain in formulations increased revealed that roasting increased the CP values much more than plain amaranth grain flour. These findings suggest that roasting as a pre-treatment method improves the protein content of jackfruit seed flour, and so provides a method for improving the protein content of high starch food items for consumers who require more protein, such as weaning children. In this study, all the formulations had a higher protein than recommended value from complementary foods (1.9 g/day at 6–8 months (21%), 4.0 g/day at 9–11 months (42%), and 6.2 g/day (57%) at 12–23 months (World Health Organisation 2011).

Crude fat (CF): The CF content of the formulations ranged from 0.9% to 6.0% (Table 1). Formulation 1 (*$J_{100}A_0$*), containing plain raw JFSF had the lowest, while F6 *($Jr_{100}A_0$)*, with plain roasted JFSF had the highest CF content. This difference could have been caused by the effects of roasting. Eke-Ejiofor et al. (2014) reported fat contents of 0.13% to 0.77% in germinated and raw jackfruit seed flours, respectively which were relatively lower than what was obtained in this study, which difference could also be attributable to the different treatments and probably variety. The CF content increased with the increase in the amount of AG in formulation containing raw JFSF, but decreased with increase in AG in formulations containing roasted JFSF. Formulations containing roasted JFSF had a fat content which is in the range proposed for weaning foods (5–20%). On varying the proportions, there was a significant difference ($p < 0.05$) in the mean fat content of the blends.

Crude fibre: The crude fibre content of the study formulations ranged from 4.4% to 10.6% (Table 1). The crude fibre was highest in F6 (roasted plain JFSF) and lowest in F11 (plain AGF). Roasting JFS caused significant differences ($p < 0.05$) in the crude fibre content of the resultant flours. The fibre content decreased significantly with the increase in the proportion of amaranth grains. The results indicated that JFSF generally had higher crude fibre content than amaranth grain flour. The results obtained in this study were however lower than those reported by Tulyathan et al. (2002) who obtained 2.36% in plain raw jackfruit seed kernel flour. The difference could be attributable to variation in variety of jackfruit and the process treatment conditions.

Carbohydrates: The carbohydrate content of the formulations ranged from 51.3% to 71.7% (Table 1), with the highest recorded in *$J_{100}A_0$* (F1) and the lowest in *$Jr_{100}A_0$* (F6). The carbohydrate content was significantly lower in formulations that contained roasted JFSF. The results obtained in raw JFSF were comparable with those reported by Kumar et al. (1988), Singh (1999), Ocloo et al. (2010) and Eke-Ejiofor et al. (2014). Increasing the AGF also reduced the carbohydrate content of raw JFSF blends while increasing it in roasted JFSF blends. The lower carbohydrate content of amaranth grain compared to JFS resulted in a reduction in carbohydrate content with increasing amaranth grain flour in raw samples, whereas the increasing carbohydrate content with increasing amaranth grain flour in formulations containing roasted JFSR could have been due to the fact that AGF contained more carbohydrate than roasted JFS. The carbohydrate content of jackfruit seed flour was lowered after roasting, according to these findings.

Calories: The caloric content of the study formulations varied from 319.8 to 355.0 Kcal/100g. F11(J_0A_{100}), which contained plain amaranth grain flour had the highest energy value, while F1 ($J_{100}A_0$), which contained plain raw JFSF had the least. Ocloo et al. (2010) reported a much higher value of 382.79 Kcal/100 g in raw jackfruit seed flour. The difference could have been as a result of differences in jackfruit varieties and or growth conditions. There were significant differences ($p < 0.05$) in the caloric values among different treatments. Formulations containing raw JFSF had lower caloric content than those containing roasted JFSF. It was also noted that increasing the amaranth grain content led to significant increase in the caloric content of the formulations; however, the energy content was higher among formulations containing roasted JFSF. This could have been caused by the increased percentage of protein and fat among the roasted samples due to moisture loss**.**

Effects of roasting on the functional properties of jackfruit seeds and amaranth grain complementary flours

Water absorption capacity (WAC): The water absorption capacity of a food material reflects the ability of the material to associate with water under conditions of limited water, and hence its ability to bind the water (Singh 2001). The WAC of the study formulations ranged from 234 g H_2O/100 g of flour and 373.6 g of H_2O /100 g of flour (Table 2). Formulation 5 ($J_{33}A_{67}$) had the lowest WAC, while F6 ($Jr_{100}A_0$) depicted the highest WAC. Significant differences ($p < 0.05$) were observed in the WAC of flours with different concentrations of jackfruit seed and grain amaranth flour. Roasting the JFS significantly increased the WAC of the flours while increasing grain amaranth grain concentrations in the composite flours decreased the WAC. It has been reported that protein and carbohydrate compositions of flour affect its water binding capacity. It can be suggested that proteins in the composite flours with a higher concentration of roasted jackfruit seeds have hydrophilic subunits and thus greater water absorption. Moreover, gelation of carbohydrates and swelling of crude fibres may also influence the water adsorption of oilseed samples (Narayana and Narasinga 1982). It was observed in the previous section that flours from roasted JFS contained higher crude fibres than those from raw JFS. These findings are in agreement with those reported by Eke-Ejiofor et al. (2014) who reported that roasted jackfruit seed flour had a higher WAC than the raw jackfruit seed flour. The WAC values in this study were however higher than those reported in literature (Ocloo et al. 2010). Flour composition and preparation methods, such as a milling time can affect some properties of the flour; for example, starch damage, which will result in high water absorption because water can penetrate into granules more easily than intact granules (Ocloo et al. 2010).

Oil absorption capacity (OAC): The OAC is a prominent factor in food formulations as it improves flavour and improves mouth feel of foods by physically entrapping oil using a complex capillary attraction process. The OAC of the study formulations was in the range of 119 to 196 g H_2O/100 g of flour. Formulation 6 (Jr_0A_0) and formulation 1 ($J_{100}A_0$) had the highest and lowest values, respectively (Table 2). Significant differences ($p < 0.05$) were observed in the OAC of the flour formulations at the different concentrations of jackfruit seed and grain amaranth flours. These results also showed that increasing grain amaranth concentrations in the composite flours led to increase in OAC in samples containing unroasted JFS but reduced the OAC in samples containing roasted JFS. Roasting jack fruit seeds significantly increased the OAC of the flours. The increase in OAC with roasting is probably due to protein decomposition and denaturation which exposes hydrophobic groups in bonding to hydrocarbon chains of oil (Turan et al. 2015). Fat content in the flour also affects the OAC of the flour. Kaushal et al. (2012) suggested that the presence of non-polar side chains increases the OAC as these bind to the hydrocarbon side chain of oil. The results above could suggest that the flours made from roasted jackfruit seed flour had a higher amount of non-polar side chains compared to those from raw jackfruit seed flour. OAC is useful in flavour retention and improves palatability of a given food (Aremu et al. 2007). These results are higher than those reported by Ocloo et al. (2010) who obtained 17% in raw JFSF. These differences could be attributable to jackfruit varietal differences and in variation in environmental and preparation conditions. The ability of the study samples to retain oil was lower than their ability to absorb and retain water. A similar observation was made by Agume et al. (2017) in their study of soybean.

Table 2: The functional properties of from jackfruit seeds and grain amaranth

Formulation	Water Absorption Capacity (g/ 100 g)	Oil Absorption Capacity (g /100 g)	Water Solubility Index (%)	Swelling Power (g/g)	Bulk Density (g/cm^3)
F1	341.3 ± 9.0^{ab}	129.5 ± 14.2^{ab}	6.5 ± 0.5^{ab}	39.0 ± 3.4^{a}	0.7 ± 0.0^{b}
F2	304.6 ± 7.2^{c}	135.4 ± 16.8^{b}	6.8 ± 0.8^{b}	42.5 ± 5.9^{a}	0.7 ± 0.0^{b}
F3	276.6 ± 6.4^{c}	139.9 ± 10.8^{ab}	7.0 ± 0.2^{a}	44.6 ± 2.7^{a}	0.6 ± 0.0^{a}
F4	258.9 ± 0.0^{c}	143.6 ± 7.1^{ab}	7.6 ± 0.7^{a}	45.4 ± 4.5^{a}	0.6 ± 0.0^{a}
F5	234.3 ± 7.3^{b}	167.6 ± 13.7^{a}	7.6 ± 0.7^{a}	46.2 ± 1.3^{a}	0.6 ± 0.0^{a}
F6	373.6 ± 8.8^{a}	196.6 ± 1.3^{a}	12.7 ± 0.5^{a}	13.3 ± 1.3^{b}	0.5 ± 0.0^{a}
F7	366.5 ± 10.5^{a}	168.8 ± 6.3^{c}	11.7 ± 0.6^{ab}	14.7 ± 0.5^{a}	0.5 ± 0.0^{a}
F8	358.9 ± 12.7^{ab}	154.8 ± 7.0^{b}	11.0 ± 0.6^{ab}	15.5 ± 1.2^{a}	0.6 ± 0.0^{a}
F19	354.8 ± 12.5^{ab}	127.8 ± 2.9^{c}	10.1 ± 0.1^{ab}	25.5 ± 1.7^{bc}	0.6 ± 0.1^{a}
F10	346.8 ± 0.5^{ab}	117.2 ± 3.7^{c}	11.2 ± 0.1^{ab}	38.3 ± 1.3^{bc}	0.6 ± 0.0^{a}
F11	314.4 ± 3.6^{c}	119.7 ± 14.0^{bc}	10.9 ± 0.1^{b}	40.4 ± 5.4^{c}	0.6 ± 0.0^{a}

Values are means ± SD, (n=3). Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: F1 = $J_{100}A_{0}$, F2 = $J_{75}A_{25}$, F3 = $J_{60}A_{40}$, F4 = $J_{50}A_{50}$, F5 = $J_{33}A_{67}$, F6 = $Jr_{100}A_{0}$, F7 = $Jr_{75}A_{25}$, F8 = $Jr_{60}A_{40}$, F9 = $Jr_{50}A_{50}$, F10 = $Jr_{33}A_{67}$, F11 = $J_{0}A_{100}$. J is raw JFSF, A is GAF and Jr. is roasted JFSF.

Water solubility index (WSI): WSI refers to the amount of soluble solids in a sample and is a parameter that measures the conversion rate of starch during processing hence reflecting amounts of released polysaccharides from starch granules (Jogihalli 2017). The WSI of the flours ranged from 6.9% to 12.7%. The WSI was highest in formulation 6 ($Jr_{100}A_{0}$) and lowest in F1 ($J_{100}A_{0}$). There were significant differences ($p < 0.05$) in the WSI of the different formulations. Roasting jackfruit seeds significantly increased the WSI of the flours. It was also observed that increasing grain amaranth concentrations increased the WSI of the flours among samples containing raw JFS, but reduced it among the samples containing roasted JFS. The differences in the WSI of the different flours can be explained by the differences in their chemical composition. Singh et al. (2003) reported WSI as being dependant on the morphological structure of starch granules such as size, shape and texture; these determine the extent which free polysaccharides are released in the presence of water (Osundahunsi et al. 2003). Therefore, the increase in WSI observed in formulations containing roasted JFSF is probably because starch was more damaged and was converted into molecules with less molecular weight (dextrin) with increasing temperatures, and it thus absorbed more water and hence increased WSI. The WSI has implications on the viscosity of pastes obtained from these flours; a low WSI indicates high cold pasting ability of the flour and hence a high final viscosity. The values obtained in this study were in the range of those reported for sweet potato flours by Jangchud et al. (2003).

Swelling power (SP): Swelling power is a measure of hydration capacity which is a weight measure of swollen starch granules and their occluded water (Asaoka et al. 1992). The swelling power of the study flours ranged between 13.3% and 46.2%. Formulation 4 ($J_{50}A_{50}$) had the highest SP, while formulation 6 ($Jr_{100}A_0$) had the lowest SP. These results are in agreement with those for raw JFSF, reported by Sandhu and Singh (2007). There were significant differences ($p < 0.05$) in the SP of the flours containing different concentrations of jackfruit seed and grain amaranth flour. The SP of the various flours increased as the grain amaranth concentrations in the composite flours increased. Except for flours with a high concentration of AG, roasting the jackfruit seeds reduced the SP of the flours. Swelling power is a measurement of swollen starch granules that indicates how much water the starch absorbs (Asaoka et al. 1992). The significant discrepancies in the data show that composite flours containing different amounts of grain amaranth and jackfruit seed flour absorb water to varying degrees. The reduced swelling power of roasted JFSF formulations can be attributed to a higher degree of intermolecular interaction than raw JFSF formulations (Kumoro et al. 2012). Swelling also occurs when amylopectins associate to form crystals; low crystallisation increases the stability of starch granules hence lowering the swelling power (Singh et al. 2003). It can be suggested that roasting jackfruit seeds and increasing grain amaranth concentrations in the flours increased the level of crystallisation of amylopectins in the flour and thus increased swelling power. Swelling is a characteristic mostly attributed to starch, but which interacts with other components such as proteins and lipids (Yellavila et al. 2015). The reduction of swelling might result from the destruction of starch granules and proteins' structure through heat-induced enzymatic hydrolysis of peptide.

Bulk density (BD): BD is a measure of heaviness of a flour sample that is important for determining packaging requirements, material handling and applications in wet processing in the food industry. The values obtained in this study ranged from 0.5 to 0.7 g/mL with F1 ($J_{100}A_0$) and F6 ($Jr_{100}A_0$) having the lowest and highest values, respectively. There were no significant differences in the BD of the different flours. Increasing grain amaranth concentrations did not significantly affect the BD of the different formulations, although results showed a slight decrease. Roasting the JFS did not significantly affect the bulkiness of the flours although it slightly lowered it. The results obtained in this study are similar to those reported by Ojinnaka et al. (2009) about modified cocoyam as having an average bulk density of 0.67 g/mL. Ocloo et al. (2010) also reported BD of 0.8 in raw jackfruit seed flour. Bulk density has implications on the viscosity of the resultant paste as the higher the bulk, the thicker the paste and the lower the bulk the lighter the paste (Adebowale et al. 2008). Low bulk density is preferred for complementary feeds as the flour can concentrate energy and nutrients in a relatively thin paste (Onimawo and Egbekun 1998). Bulk density has implications on determining requirements for packaging, transportation and storage as less bulky flours are lighter and therefore easier to handle.

Peak viscosity (PV): Peak viscosity, which is the maximum viscosity attained during cooking is an indication of paste strength of flour. The PV of the flours ranged between 326.5 and 1292 RVU, with F6 ($Jr_{100}A_0$) and F11 (J_0A_{100}) having the lowest and highest values, respectively (Table 3). Significant differences ($p < 0.05$) were observed among the PV values of the different flours. Swinkels (1985) reported that peak viscosity reflects the strength of pastes formed during gelatinization; a process where starch granules absorb water, swell and form gel. The results revealed increase in PV with addition of increasing quantities of AG. Roasting of JFS on the other had significantly reduced the PV of the flours. It has been reported that starch and protein compositions of the flours affect their peak viscosity (Morris et al. 1997). The increase in PV observed with increase in AG flour could be due to the high protein concentration (17%) in grain amaranth flour which could have led to increase the overall swelling power of the flour. These results are in the range of those reported by Awolu (2017) in a study on pearl millet based composite flour with a PV of 462 RVU.

Breakdown viscosity (BDV): Breakdown viscosity is the measure of degree of starch granule disintegration during heating (Dengate 1984). The breakdown viscosity of the flours ranged from 17.0 to 417 RVU, with F11 (J_0A_{100}) and F1 ($Jr_{100}A_0$) and having the highest and lowest values, respectively. The BDV values of the different flours were significantly different ($p < 0.05$). Increasing grain amaranth proportions of flours increased their BD. Roasting was also found to lower the BDV of the samples. Farhat et al. (1999) reported that a low BDV value indicated a high stability of starch granules within the flour. Low breakdown viscosity is also an indication of low swelling tendency.

Table 3*:* Pasting properties of composite flours from jackfruit seeds and amaranth grains

Formulation	Peak viscosity (RVU)	Breakdown Viscosity (RVU)	Setback viscosity (RVU)	Final Viscosity (RVU)	Peak Time (min)	Pasting Temp. (°C)
F1	404.00^{ef}	24.00^{c}	263.00^{bc}	625.00^{de}	7.00^{a}	81.35^{bc}
F2	489.00^{ef}	$40.0.00^{c}$	176.00^{cd}	650.00^{de}	6.90^{a}	90.13^{a}
F3	859.67^{cf}	48.33^{c}	212.00^{cd}	1023.33^{abc}	5.96^{a}	83.56^{abc}
F4	1131.00^{ab}	224.00^{b}	323.00^{b}	1230.00^{a}	5.60^{a}	79.0^{c}
F5	970.00^{bc}	179.33^{b}	283.67^{b}	1074.33^{abc}	4.09^{a}	79.83^{c}
F6	326.50^{f}	17.00^{c}	138.50^{d}	432.00^{e}	7.00^{a}	81.35^{bc}
F7	457.00^{ef}	20.00^{c}	156.00^{d}	596.00^{de}	6.80^{a}	87.83^{ab}
F8	596.00^{def}	25.00^{c}	191.00^{cd}	767.00^{cde}	6.33^{a}	84.22^{abc}
F9	652.00^{de}	31.33^{c}	198.67^{cd}	819.33^{bcd}	6.09^{a}	83.60^{abc}
F10	1021.50^{abc}	144.00^{b}	254.00^{bc}	1131.50^{ab}	5.20^{a}	79.586^{c}
F11	1292.00^{a}	417.00^{a}	459.50^{a}	1334.50^{a}	5.167^{a}	81.35^{bc}

Values are means, (n = 3). Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: F1 = $J_{100}A_0$, F2 = $J_{75}A_{25}$, F3 = $J_{60}A_{40}$, F4 = $J_{50}A_{50}$, F5 = $J_{33}A_{67}$, F6 = $Jr_{100}A_0$, F7 = $Jr_{75}A_{25}$, F8 = $Jr_{60}A_{40}$, F9 = $Jr_{50}A_{50}$, F10 = $Jr_{33}A_{67}$, F11 = J_0A_{100}. J is raw JFSF, A is GAF and Jr is roasted JFSF.

Setback viscosity (SBV): The setback viscosity reflects the degree of retrogradation and reordering of starch molecules during cooling. The flours had setback viscosity that ranged from 138.5 to 459.5 RVU, with F11 (J_0A_{100}) and F6 ($Jr_{100}A_0$) having the highest and lowest values, respectively. The setback viscosity increased with increase in grain amaranth concentrations, however decreased among the samples with roasted jackfruit seeds. Significant differences ($p < 0.05$) were observed in the SBV of the various flours. These results were in agreement those reported by Agume et al. (2017), who observed decrease in SBV with roasting of soybean.

Final viscosity (FV): The final viscosity of the flours ranged from 432 to 1334.5 RVU with F11 (J_0A_{100}) and F6 ($Jr_{100}A_0$) and having the highest and lowest values, respectively. Increasing AG concentrations increased the FV of the slurries from the flours. Roasting the jackfruit seeds however decreased the FV values. This parameter is an indicator of stability of a cooked paste (Ragaee and Abdel-Aal 2006). High final viscosity signifies increased ability to form a viscous paste.

Sensory characteristics and consumer acceptance of complementary porridges prepared from jackfruit and amaranth grain flours

The effects of roasting and inclusion of amaranth grain on the sensory characteristics and consumer acceptability of the complementary porridges made out of blending jackfruit seed with amaranth grain are presented in Table 4. There were significant differences ($p \leq 0.05$) among the porridges in appearance and flavour, but there was no significant difference ($p \geq 0.05$) in the colour, taste and aroma of the porridges. Porridges from flours containing roasted JFSF flour had higher mean scores in appearance, flavour, taste, aroma, flavour and overall acceptance. The relatively higher mean score in flavour and aroma in porridges containing roasted jackfruit seed flour were due to the roasted flavour and aroma imparted on seeds. These results are similar to those obtained by Adedeji et al. (2015) using soybeans. Controlled roasting of food materials causes development of desirable roasted aroma due to the formation of pyrazine compounds that also reflects the extent of browning colour development in the product (Powrie and Nakai 1981). It was also observed that increasing the amaranth grain flour led to higher mean scores for all attributes and consumer acceptability in porridges containing both raw and roasted jackfruit seeds. However, porridges containing plain amaranth grain flour registered the lowest mean scores in aroma, taste and overall acceptance. These results are in agreement with other results reported by Mridula et al. (2007) who observed low for acceptance and other sensory attributes in products made using unroasted soybean flour. The overall acceptability of the porridges ranged from 4.0 to 7.3. F11 *($J_{100}A_0$)* and F10 (*$Jr_{33}A_{67}$)* had the lowest and highest values, respectively (Table 4). There were significant differences in the general acceptance of the formulated porridges. Increasing amaranth grain flour proportions in both raw and roasted JFSF increased acceptability, but formulations containing roasted JFSF were preferred more than those that contained raw JFSF, specifically F10 (*$Jr_{33}A_{67}$)*.

Table 4: Sensory characteristics and overall acceptance of composite flours from jackfruit seeds and amaranth grain

Formulation	Sensory attributes					
	Appearance	Colour	Flavour	Aroma	Taste	Acceptance
F1	6.3 ± 0.6^{ab}	7.7 ± 1.5^{a}	5.0 ± 1.0^{a}	4.3 ± 2.1^{a}	4.3 ± 1.2^{a}	4.7 ± 1.2^{a}
F2	6.3 ± 0.6^{ab}	6.0 ± 1.0^{a}	5.3 ± 0.6^{a}	5.0 ± 0.0^{a}	4.7 ± 0.6^{a}	5.0 ± 0.0^{a}
F3	7.0 ± 0.0^{b}	6.3 ± 0.6^{a}	6.0 ± 0.0^{ab}	6.3 ± 0.6^{a}	5.7 ± 1.2^{a}	5.7 ± 1.0^{ab}
F4	5.3 ± 0.5^{a}	6.1 ± 0.2^{a}	5.2 ± 0.2^{a}	5.2 ± 0.2^{a}	4.3 ± 0.2^{a}	6.0 ± 1.2^{a}
F5	4.0 ± 1.7^{a}	6.4 ± 0.6^{a}	6.0 ± 1.0^{ab}	5.3 ± 1.5^{a}	5.7 ± 1.2^{a}	6.3 ± 0.6^{ab}
F6	7.0 ± 2.1^{b}	6.6 ± 0.3^{a}	6.0 ± 0.0^{ab}	6.4 ± 2.1^{a}	6.1 ± 0.3^{a}	6.5 ± 0.7^{ab}
F7	6.3 ± 0.8^{ab}	6.8 ± 0.1^{a}	6.2 ± 0.2^{ab}	6.2 ± 0.0^{a}	6.0 ± 2.1^{a}	6.6 ± 0.9^{ab}
F8	7.2 ± 0.9^{a}	6.7 ± 0.1^{a}	6.3 ± 0.1^{ab}	6.2 ± 1.0^{a}	6.2 ± 2.2^{a}	6.9 ± 0.3^{b}
F9	7.0 ± 1.0^{b}	6.7 ± 2.1^{a}	6.3 ± 2.1^{ab}	6.3 ± 1.2^{a}	6.3 ± 1.2^{a}	7.0 ± 2.1^{b}
F10	7.7 ± 1.2^{b}	7.0 ± 2.0^{a}	7.3 ± 1.5^{b}	6.7 ± 1.5^{a}	6.7 ± 1.5^{a}	7.3 ± 1.5^{b}
F11	5.3 ± 2.1^{a}	6.3 ± 1.2^{a}	4.3 ± 1.2^{a}	4.3 ± 1.2^{a}	4.0 ± 1.7^{a}	4.0 ± 1.5^{a}

Values are means ± SD, (n = 3). Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: F1 = $J_{100}A_{0,}$ F2 = $J_{75}A_{25,}$ F3 = $J_{60}A_{40,}$ F4 = $J_{50}A_{50,}$ F5 = $J_{33}A_{67,}$ F6 = $Jr_{100}A_{0,}$ F7 = $Jr_{75}A_{25,}$ F8 = $Jr_{60}A_{40,}$ F9 = $Jr_{50}A_{50,}$ F10 = $Jr_{33}A_{67,}$ F11 = $J_0A_{100.}$ J is raw JFSF, A is GAF and Jr is roasted JFSF.

Conclusion

The results from this study showed that roasting has marked effects on the proximate, functional, pasting and sensory properties of the jackfruit seed and amaranth grain blend composite flour. Roasting the jackfruit seeds and inclusion of amaranth grain flour proportions increased the proximate components: total ash, crude protein, and crude fat content of the formulation and increased the caloric content as well. Roasting the jackfruit seeds and inclusion of amaranth proportions in the complementary flour blend led to changes in the functional properties of the flour; decreased the water absorption capacity, oil, absorption capacity and swelling power, but increased the water solubility index. Roasting of jackfruit seeds led to significant reduction in all the pasting properties, while inclusion of amaranth grain flour in increasing proportions increased all the pasting viscosities; pasting, breakdown, setback and final viscosities. Roasting JFS and inclusion of amaranth grain flour in increasing proportions led to improvements in the all scores of the sensory attributes of the porridges prepared from the flour blends and significantly increased overall acceptability of the porridges. These results show that utilization of amaranth and roasting jackfruit seed kernel for the production of complementary flours is a possible avenue for combating the problem of malnutrition among young children in low income countries like Uganda. The technique used in this study provides an opportunity to increase porridge solids content and in so doing yields nutrient-dense and acceptable porridges for complementary feeding. This process can also be easily adopted at household level and this can help enhance the nutritional status of children.

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