Proximate and Physicochemical Properties of Flours from Improved Sorghum and Cassava Varieties Grown in Awka, South Eastern Nigeria

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Received:- 10 October 2022/ Revised:- 17 October 2022/ Accepted:- 22 October 2022/ Published: 31-10-2022

Abstract— *Flours are among the essential raw materials used in industries such as food, pharmaceutical and other industries for the production of different products. Scarcity and undesirable qualities of flours now lead to search for plant materials of improved qualities from which flours of high value can be isolated. Improved variety of sorghum and cassava from the Anambra State Agricultural Development Program (ADP) were employed in this research. The proximate and physicochemical analyses were done using standard methods. Results showed that the sorghum and cassava yielded 44.8% and 68.7% quantities of pale white and white colour respectively with neutral pH. Sorghum flours had 4.35±0.11%, 2.6±0.23%, 0.26±0.03%, 3.28±0.06%, 2.16±0.10% and 25.02±1.02% respectively for moisture, ash content, fat content, crude protein, crude fibre and carbohydrate content. Cassava flour gave 5.24±0.58% (moisture), 3.35±1.02% (ash), 0.18±0.45% (fat), 1.02±0.33% (crude protein), 3.14±2.02% (crude fibre) and 28.06±0.54% (carbohydrate). Sorghum flour isolated also had 240.6±1.3%, 123.1±0.8%, 800.5±2.0%, 3.5±3.1%, 22.5±0.5%, 67.0±0.7 and 0.78±0.2% for water absorption capacity, oil absorption capacity, swelling power, solubility index, amylose content, amylopectin content and bulk density respectively while cassava flour showed 260.4±2.0% (water absorption capacity), 128.0±1.1% (oil absorption capacity), 744.3±2.2% (swelling power), 4.3±2.0% (solubility index), 32.0±1.2% (amylose), 78.0±0.2% (amylopectin) and 0.89±0.1% (bulk density). The two isolated flours showed good pasting properties with peak viscosity and final viscosity of 2215±2RVU and 1126±2 RVU for sorghum flour and 3204±5 RVU and 1422±3 RVU for cassava flour. It is therefore deduced that flours isolated from the improved sorghum and cassava varieties will be suitable and cheap source of raw material for food, pharmaceutical and other industries due to their high qualities.*

Keywords— Cassava, Sorghum, Flour, Industries, Improved variety.

I. INTRODUCTION

Guinea corn (*Sorghum bicolar*) is a grass specie cultivated for its grain which is used as energy food. It belongs to the grass family poaceae (Al-Suwaiegh *et al.,* 2002). It originated in Africa about 3000 to 5000 years ago (Odibo *et al.,* 2002; Sophina *et al.,* 2017). The crop is environmental friendly, water-efficient, requires little or no fertilizer, can resist pest attack and its refuse is biodegradable (FAO, 1995, Al-Suwaiegh *et al.,* 2002). The grains are consumed as food as well as being used in industries like brewing industries for malt production (Ogbonna and Okolo, 2005; Sophina *et al.,* 2017).

Cassava (*Manihot esculenta* Crantz) is a perennial shrub with an edible starchy root, which grows in the tropics and sub-tropical areas of the world (Burrell, 2003; Umeh, 2011).

Food and Agriculture Organisation, FAO, (FAOSTAT, 2011) estimates the world production of cassava at more than 230 million metric tonnes annually with major producing countries to

include Nigeria, which produced 37.5 million tonnes per annum (Hasmadi *et al.,* 2020). Cassava ranks second only to cereal grains as the chief source of energy in Nigerian diet

(Umeh, 2011). By this, cassava plays an important role in alleviating African food crises, though poor in protein (about 1.2%) and rich in cyanide (>10mg/100g fresh weight) in some varieties (Nwabueze and Odunsi, 2006; Cumbana *et al.*, 2007; Umeh, 2011). Cassava varieties cultivated in different regions differ in their nutritional, proximate and other physicochemical properties (Cumbana *et al.,* 2007; Hasmadi *et al.,* 2020). In the tropics, cassava is the most important root crop and as source of energy, the calorific value is high compared to most starchy crops (Hasmadi *et al.,* 2020). Cassava root contains a number of mineral elements, in appreciable amounts, that are useful in the human diet. The root contains significant amounts of iron, phosphorus and calcium, and is relatively rich in vitamin C (Enidiok *et al.,* 2008; Hasmadi *et al.,* 2020).

It is an important component in the diets of many people around the world (FAO, 2007) and is the third-largest carbohydrate food source within the tropical regions, after rice and corn (Ceballos *et al.,* 2006; Hasmadi *et al.,* 2020). Cassava is a food security crop (Barratt *et al.,* 2006) and the roots can be left inside in the soil for up to two years without spoilage. Cassava cannot be consumed as a fresh food item due to its cyanide content but can be processed into various food and non-food products, such as starch, flour, beverages, animal feeds, biofuels and textiles (Tewe and Lutaladio, 2004; Hasmadi *et al.,* 2020). The nutritional value of cassava roots is important because they are the main part of the plant consumed in developing countries. However, there is much variation in the nutrient quality of the cassava root depending on several factors, such as geographic location, variety, age of the plant, and environmental conditions (Benesi *et al.,* 2007; Sanni *et al.,* 2008; Montagnac *et al.,* 2009).

Sorghum grains and cassava tubers can be preserved by processing them into flours. The flours are employed in baking, pharmaceuticals, food and other industries for production of different products. This work therefore determined the proximate and physicochemical properties of flours of improved cassava variety (TMS 30555), called *Onuanwuru* and improved sorghum variety (SC 114) cultivated by the Anambra State Agricultural Development Program (ADP).

II. MATERIALS AND METHODS

2.1 Collection of materials

Dry grains of sorghum (Guinea corn) variety (SC 114) and 9 months old freshly harvested cassava tubers, (*Manihot esculenta* Crantz), (TMS 30555) called '*Onuanwuru*' were collected from the Anambra State Agricultural Development Program (ADP) office in Awka and taken to the Laboratory of the Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University, Awka for the research.

Chemical and reagents used were purchased from the Onitsha Bridge Head Drug market and they were of high analytical grade.

2.2 Processing the cassava tubers into flour

The method of Kaur *et al.,* (2016) was modified and used to process the cassava tubers into flour. Three kilogram (3kg) of the fresh tubers were peeled, washed, cut in smaller pieces and soaked in 5 litres of water using a plastic bucket. The tubers were steeped for 2 days at room temperature (28±2ºC), washed, hard fibres removed and dried in the oven at 60ºC for 10 hrs and allowed to cool. They were ground with a blender and sieved with 0.1 mm sieve to obtain the cassava flour which was oven dried again in a tray for another 3 hrs at 50ºC and stored in an airtight container.

2.3 Processing the sorghum grains into flour

The method of Umerie and Umeh, (2016) was used in processing the sorghum flour. One hundred kilograms (100Kg) of the dried grains were weighed into a flat tray. The grains were sorted to remove stones, sand and other unwanted substances therein. They were soaked in 2 litres of water containing 0.813g of Potassium metabisulphite for 48 hrs at 30±1ºC. The grains were removed from the steeping water and milled with a Moulinex type electric blender to slurry. The slurry was re-suspended in distilled water, stirred and allowed to stand for 5 minutes. It was then filtered through a 100-mesh sieve cloth for coarse sieving. The sediment was re-suspended in distilled water, stirred and allowed to stand for another 12 hrs. The supernatant was again decanted and the sediment passed through a 200-mesh sieve for fine sieving. The suspension was allowed to settle for another 8 hrs and excess solution decanted. The resulting slurry/sediment was slurried in 200 ml of distilled water, sediment and decanted twice. The recovered wet flour was dried for 24 hrs in a tray in the oven set at 40ºC. The resulting flour was crushed using a blender and oven dried again in a tray at 50ºC for 3 hrs and stored in an airtight container.

III. ANALYSIS OF THE FLOURS

3.1 Proximate analysis of the flours

Total moisture content, total ash, crude fat, crude protein, crude fibre and total carbohydrates were determined using AOAC (2000).

3.2 Physicochemical analysis of the flours

3.2.1 Water Absorption Capacity (WAC)

WAC of flours was determined using the method used by Raphael *et al.,* (2022). One gram (1g) of the flour sample was mixed with 10 ml distilled water in a 15 ml graduated centrifuge tubes and stirred on a vortex mixer for 5 min. The mixture was allowed to stand for 30 min at room temperature, centrifuged at 3000 rpm for 15 minutes and the supernatant carefully decanted. The weight of the wet flour in the tubes was determined and the Water absorption capacity of the flours was calculated using the equation:

$$\%\text{Water Absorption Capacity } (\%\text{WAC}) = \frac{\text{Weight of absorbed water}}{\text{Weight of flour}} \times 100$$

3.2.2 Oil Absorption Capacity (OAC)

OAC of the flours was determined using the method of Chandra and Samsher (2013) as modified by Raphael *et al.,* (2022). One gram (1g) of each sample was dissolved in 10 ml of vegetable oil in a 15 ml graduated centrifuge tubes and then stirred on a vortex mixer for 5 minutes. The mixture was allowed to stand for 30 min at room temperature, centrifuged at 3000 rpm for 15 minutes and the supernatant carefully decanted. The oily flour mixture in the tubes was weighed and Oil Absorption Capacity was calculated using the formula:

$$\%\text{Oil Absorption Capacity } (\%\text{OAC}) = \frac{\text{Weight of oil absorbed}}{\text{Weight of flour}} \times 100$$

3.2.3 Swelling power and solubility index

Swelling power and solubility index of the flours were determined using the method used by Raphael *et al.,* (2022). Approximately one gram (1g) of the flours was mixed with 10 ml of distilled water in a 15 ml graduated centrifuge tube and heated at 85°C for 30 minutes in a water bath. The resulting slurries were allowed to cool to room temperature and centrifuged at 3000 rpm for 15 minutes Decanted supernatants were evaporated in an electric hot air oven at 105°C for 30 min. The dried supernatants and sediments were weighed. Swelling power and solubility index were calculated using the equations:

$$\%\text{ Swelling Power} = \frac{\text{Weight of paste}}{\text{Weight of flour}} \times 100$$

$$\%\text{ Solubility Index} = \frac{\text{Weight of soluble fraction}}{\text{Weight of flour}} \times 100$$

3.3 Determination of the colour of the flours

The colour of sorghum and cassava flours was determined using Hunter Colour Meter.

3.4 Determination of the bulk density of the flours

Bulk density of the flours was determined according to the method used by Raphael *et al.,* (2022). A one hundred gram (100g) of the different flours was weighed and gently filled in 250 ml measuring cylinder. The bottom of the cylinder was gently tapped until there was no further diminution of the sample level. The final volume of the flour in the measuring cylinder was noted and Bulk density of the flour was expressed as:

$$\text{Bulk density} = \frac{\text{Weight of sample (g/m)}}{\text{Unit volume of sample}} \times 100$$

3.5 Determination of the pasting properties of the flours

Viscosity of the flours was determined using the method of Williams *et al.,* (2019) as described by Rapheal *et al.,* (2022). A paste was formed in pre-weighed canister from each sample using sample mass and volume of water calculated from the moisture content of the respective samples. The canister with the formed paste was fixed into the Rapid-Visco Analyzer. Each suspension was kept at 50°C for 1 min and then heated to 95°C in 7 minutes with a holding time of 5 minutes followed by cooling to 50°C in 7 minutes with a 1-min holding time. The pasting parameters (Peak viscosity, Trough viscosity, Breakdown viscosity, Final viscosity and Setback viscosity) were read from the screen of the analyzer and recorded as Rapid-Visco Analyzer unit (RVU).

3.6 Determination of *pH* of the flour samples

The pH of the cassava flour was determined using Hanna Model pH-meter as described by Umeh (2011). One gram of each flours were thoroughly mixed in 10 ml of distilled water in centrifuge tubes and the electrode of the pH-meter, already standardized to pH of 7 was immersed and the readings on the screen recorded.

3.7 Determination of Amylose and Amylopectin content of the flours

Amylose and Amylopectin content of the isolated flours were done as described by Raphael *et al.*, (2020).

3.8 Statistical analysis

All the experiments were carried out in triplicates and the data analysed were the mean values of the results obtained. Data analysis was done using T-test performed using SPSS software version 23.0.

IV. RESULTS AND DISCUSSION

Appreciable quantities of flour were isolated from the sorghum grains and cassava tubers as presented in Table 1. Sorghum grains gave flour yield of 44.8% while cassava tubers yielded 68.7 % flour. This compared well with the findings of Umerie and Umeh (2016) that found starch yield from another *Digitaria exilis,* a related grain to be 35.8%. The results also

confirmed the findings of Chandra and Samsher (2013) who found flour yield from rice grain to be up to 45.4%. The results showed that grains can yield a good quantity of flour. Moisture

content of the flours was 7.35±0.11% and 9.24±0.58% for sorghum and cassava flours respectively. Based on the study conducted by Chandra and Samsher (2013), moisture content of wheat, rice, green gram and potato flours were 13%, 11%, 8% and 9% respectively. This shows that the sorghum and cassavas flour have very low moisture content compared to other types of flour. Low moisture content in sorghum and cassava flours is desirable since this will improve the palatability of the flours (Cumbana *et al.,* 2007). The research done by Hsu *et al.* (2003) reported that high quality flour usually contains moisture content range from 9.0% to 12.0%. Moisture is an important factor in the storage of flours, very high levels greater than 12% can allow microbial growth and the flour will deteriorate in a short time. Low moisture content in flour samples are favourable and confer longer shelf life to the flour. All the samples had good moisture levels and hence have the potential for better shelf life.

The values for ash contents were higher compared to the results obtained by Rodríguez-Sandoval *et al.* (2008) who postulated that ash content of flours range from 0.1% to 0.7% (Hasmadi *et al.,* 2020). The high ash contents in this work suggested that the flours contain high minerals (Hasmadi *et al.*, 2020). Niba *et al.* (2001) postulated that the high ash composition of cassava flour can be attributed to the mineral content of the soil from where the tubers were cultivated. The high ash content may also be due to the fact that the crops used are improved varieties.

Fat content of flours was within the range found by Moorthy (2002) which is between 0.19% to 0.98% (Hasmadi *et al.,* 2020). Fat content of flours influence its pasting properties. The high ash and low fat contents in these flours are desirable attribute since too much fat will lead to the high possibility for rancidity and increase cloudiness in the flour (Mishra and Rai, 2006; Hasmadi *et al.*,2020). Researchers had found out that high fat content causes low swelling power and solubility in flour (Roa *et al.,* 2014).

Crude protein content of the flours in this research was 3.28±28% and 1.02±0.33% for sorghum and cassava respectively. This indicates that sorghum flour had a higher crude protein than the cassava flour. The finding supports the finding of other researchers who postulated that cassava had a low protein content range of 1-3% (Ceballos *et al.,* 2008; Umeh *et al.,* 2014; Hasmadi *et al.,* 2020).

Crude fibre of the isolated flours corresponds with the findings of other researchers who had found cassava flour to possess crude fibre in the range of 1.66 - 4.27% (Fakir *et al.,* 2012; Hasmadi *et al.,* 2020).

Total carbohydrate content of the flours was high. This confirms the findings of Umeh *et al.*, 2014; Hasmadi *et al.*, (2020) that the large composition of tubers and grain composition is made of starch. The findings in this work on the proximate composition of the flours showed that high grade flours were obtained from the sorghum and cassava varieties.

TABLE 1
PROXIMATE COMPOSITIONS ON THE ISOLATED FLOURS

Parameters (%)	Sorghum flour	Cassava flour
Moisture content	4.35±0.11	5.24±0.58
Ash content	2.16±0.23	3.35±1.02
Crude fat	0.26±0.03	0.18±0.45
Crude protein	3.28±0.06	1.02±0.33
Crude fibre	2.16±0.10	3.14±2.02
Total carbohydrate	25.02±1.02	28.06±0.54
Flour yield	44.8	68.7

Result of Physicochemical properties of the flours isolated from the sorghum grains and cassava tubers were shown in Table 2. The flour of Sorghum and cassava showed very high percentage of water absorption capacity, oil absorption capacity, swelling power and solubility index. Water absorption capacity (WAC) is an index of the maximum amount of water a food product absorbs and retains while oil absorption capacity is an index of the maximum amount of oil a product can absorb and retain. Oil absorption capacity (OAC) is a very important parameter for determining the flavour retaining ability of flours and starches (Raphael *et al.*, 2022). The high WAC seen in the work supported the findings of Hasmadi *et al.*, (2020) who also found very high WAC (1.12±0.05 ml/g and 1.30±0.11 ml/g) from two cassava samples from different locations in Malaysia. Raphael *et al.*, 2022 also determined very high WAC (263.9±19.3 and 263.3±7.3%) and OAC (121.0±13.3 and 119.0±63%) from the research on two cassava varieties in Ghana.

According to Aryee *et al.* (2006) as reported by Hasmadi *et al.*, (2020) the water absorption capacity of flours depends on the power of aggregation between starch molecules. Weak aggregation power between starch molecules causes the surface of its molecules to form a bond with water molecules become easier thus increase the rate of water absorption capacity. Water absorption capacity of flour is an important feature in order to increase its application in ready-to-eat food such as instant noodles, dough and soup (Singh, 2001; Hasmadi *et al.*, 2020).

Oil absorption capacity is highly related to lipophilic properties of the starch molecule in the sorghum and cassava flour. Flours with high OAC are used as raw materials in producing lipid-based products for help in flavour retention and organoleptic enhancement. It also helps in absorption of vitamins in food (Raphael *et al.*, 2022).

Swelling power determines the tendency of a substance to be hydrated and stands as one of the ways of measuring food quality. Swelling power of flour and starch is inversely proportional to solubility index. The high swelling power recorded resulted in a correspondingly low solubility index seen in the work.

TABLE 2
WAC, OAC, SWELLING POWER AND SOLUBILITY INDEX OF THE ISOLATED FLOURS

Parameters (%)	Sorghum flour	Cassava flour
WAC	240.6±1.3	260.4±2.0
OAC	123.1±0.8	128.0±1.1
Swelling power	800.5±2.0	744.3±2.2
Solubility index	3.5±3.1	4.3±2.0

Key: WAC – Water Absorption Capacity; OAC - Oil Absorption Capacity

Other physicochemical properties of the sorghum and cassava flours were recorded in Table 3. Amylose content of the flours were 22.5±0.5% and 32±1.2% for sorghum and cassava flours while their amylopectin contents were 67±0.7% and 78±0.2%

respectively. Amylose and amylopectin ratios affect swelling and solubility characters of flours. They also help in stronger intermolecular interaction and higher hydrophobicity and account greatly for greater swelling power and lower solubility (Raphael *et al.*, 2022). High values of amylose and amylopectin result in low solubility of flours. Flours with low solubility indices against high swelling powers are suitable for making dough with high elasticity. The flours isolated from this research can be suitable for dough moulding. The results of amylose and amylopectin is in line with the findings of Raphael *et al.*, (2022).

Bulk density was 0.78±0.2 and 89.01g/cm^3 for sorghum and cassava flour respectively. The value of the bulk density of the two samples were low and comparable with the values obtained by Hasmadi *et al.*, (2020) who recorded 0.57±0.05 and 0.79±0.13g/cm^3 for two different cassava varieties in Malaysia. Bulk density is a measure of the heaviness of a flour sample (Hasmadi *et al.*, 2020). Previous works reported that Bulk density is generally affected by the particle size and density of the flour and it is one of the essential parameters in determining the type of packaging material, handling and application in the food industry (Hasmadi *et al.*, 2020).

pH of the isolated flours were 6.6±0.05 for sorghum and 6.8±0.02 for cassava flours. The *pH* values were high tending towards neutrality. Sorghum grains are not acidic in nature and their flours will not in any way harbour acidity unless as a contaminant during the processing methods. Cassava tubers are known to be acidic and their flours had been found to have a *pH* range of 5.5 to 8.5 (Aryee *et al.*, (2006). Other researchers (Muzanila *et al.*, 2000; Apea-Bah *et al.*, 2011) had recorded *pH* values of 6.22 in Tanzania and 5.07 and 6.65 range in Ghana respectively. The value obtained for cassava in this work may be as a result of the improved variety used. Agricultural Development Programs are currently researching and improving the cassava varieties to contain lower levels of hydrogen cyanide (HCN) and acidity. *pH* is one of the important attributes in order to maximize the application of cassava flour in food industries especially in the making of bakery products (Aryee *et al.*, 2006; Hasmadi *et al.*, 2020). Colour of the isolated flours was pale white and white respectively for sorghum and cassava which are standard flour colours suitable for industrial application.

TABLE 3

OTHER PHYSICOCHEMICAL PROPERTIES OF THE SORGHUM AND CASSAVA FLOURS

Parameters	Sorghum flour	Cassava flour
Amylose content (%)	22.5±0.5	32.0±1.2
Amylopectin (%)	67.0±0.7	78.0±0.2
Bulk density (g/cm^3)	0.78±0.2	0.89±0.1
pH of flours	6.6±0.05	6.8±0.02
Colour	Pale white	White

Table 4 presents the pasting properties of the flours isolated in this work. Pasting property is one the vital properties which measures the ability of flour or starch to form a paste. It is a parameter that cannot be sidelined in the measurement of the quality of flour and starch since it dictates the textural integrity of products (Adebowale *et al.*, 2011; Raphael *et al.*, 2022). Peak viscosity is the measure of the highest viscosity a starch granule can attain before collapsing (Adebowale *et al.*, 2011). Higher peak viscosities lead to lower pasting times and temperatures. The peak viscosity in this research is high and makes them good as industrial raw materials. Breakdown viscosity of the flours was low. The breakdown viscosity of any material is its ability to withstand thermal treatment when incorporated in any manufacturing process. The breakdown viscosity shows the resistance of the paste to shear stress and the stability of the paste during thermal treatment. Lower breakdown viscosities dictate the tenacity of the paste to thermal and shear interruptions, which are very vital in determining the stability of pastes (Raphael *et al.*, 2022). Other pasting properties were in the range that confers durability and acceptance to the isolated flours.

TABLE 4
PASTING PROPERTIES OF THE ISOLATED FLOUR

Parameters	Sorghum flour	Cassava flour
Peak viscosity (RVU)	2215±2	3204±5
Trough viscosity (RVU)	1003±2	2115±1
Breakdown viscosity (RVU)	123±1	214±2
Setback viscosity (RVU)	240±3	406±3
Final viscosity (RVU)	1126±2	1422±3
Pasting temperature °C	68±2	72±2
Pasting time (minutes)	6.2±3	5.2±1

Key: RUV - Rapid-Visco Analyzer unit.

The findings in this research conform to most of the flour characteristics already in the market. The sorghum and cassava varieties used were improved varieties from the Anambra State Agricultural Development Program and this is the first institutional research performed on them. Sorghum and cassava flours isolated from them can make good industrial flours.

V. CONCLUSION

These improved sorghum and cassava varieties were able to yield high quantity of flours greater than other varieties from literature. Their physicochemical and functional properties show encouraging characteristics for them to be used in various industries. The values of their pasting properties also made them food flours for food as well as pharmaceutical industries.

ACKNOWLEDGEMENT

I acknowledge the Tertiary Education Trust Fund (TETFUND) for creating and funding the Institution Based Research (IBR) Grant which granted the opportunity and funding of this research work.

I also appreciate the management of Nnamdi Azikiwe University, for the effort in processing my Proposal which gave me the opportunity to access and perform this work.

I acknowledge my Co-Researchers for working assiduously to see that we did the work effectively and meet the demand.

To all those who helped in one way or the other to achieve this goal, I say thank you all.

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