Comparative study of *"Tuwo"* made from maize, sorghum and rice

Sunmonu[1], B.A., Tajudeen[1], Z.O., Adeyanju[2], E.B., Oloso[3], S.E., Salmon[4], R.Y., & Akinsola[3], A.O.

[1]Department of Food Technology, Federal Polytechnic Offa, Kwara state, Nigeria
[2]Department of Home Economics, Federal University of Education, Ondo, Ondo State, Nigeria
[3]Department of Home Economics, Federal College of Education (Special), Oyo, Oyo State, Nigeria
[4]Department of Home Economics, Federal College of Education, Abeokuta, Ogun State, Nigeria.
Corresponding author: akinsola.akinjide1333@fcesoyo.edu.ng

Abstract: Comparative study of *tuwo* made from maize, sorghum and rice were investigated. The samples were coded as sample TML (Maize tuwo), TSL (sorghum tuwo) and TRS (rice tuwo) and analyzed for nutritional, chemical and sensory attributes such as taste, texture and overall acceptability. Proximate composition shows that moisture content ranged from 11.34 - 15.67 %; protein 9.53 - 11.63 %; fat 2.34 - 2.59 %; fibre 1.53 - 1.65 %; ash 1.27 - 1.42 % and carbohydrate content from 69.43 - 71.57 %. Selected mineral content evaluated shows that calcium content ranged from 7.39 - 8.17 mg/100g; magnesium 4.05 - 4.66 mg/100g; potassium 6.14 - 6.79 mg/100g; manganese 4.57 - 5.01 mg/100; zinc 3.85 - 4.39 mg/100g and iron content from 2.64 - 2.94 mg/100g. Functional properties shows that bulk density ranged from 0.74-0.79 mg/100g; water asorption capacity 2.47 - 2.67 %; oil absorption capacity 2.67 - 2.95 %; emulsion capacity 4.88 - 4.99 %; emulsion stability 39.44 - 38.37 %; foam capacity 33.51 - 36.43 %; foaming stability 14.75 - 15.17 %; swelling capacity 2.84 - 2.89 %; swelling index 1.85 - 1.95 %; dispersibility 73.00 - 76.00 %; gelatinization temperature 64.00 - 70.00 ºC while its starch content from 69.38 - 76.12 %. Pasting properties shows that peak viscosity ranged from 333.10 - 381.21 RVU; trough 138.01 - 187.21 RVU; breakdown 110.61 - 187.21 RVU; final viscosity 218.21 - 311.21 RVU; setback 143.61 - 172.51 RVU; peak time 5.25 - 5.30 min and pasting temperature from 83.66 - 84.51 ºC. Sensory attributes mean scores shows that all the samples were acceptable by the panelist however; sample TSL (sorghum sample) was rated highest. The result obtained shows the nutritional and chemical properties of tuwo flour and its sensory acceptability can best be produced from sorghum because of it high nutritional content and overall acceptability by the panelist.
[Sunmonu, B.A., Tajudeen, Z.O., Adeyanju, E.B., Oloso, S.E., Salmon, R.Y., & Akinsola, A.O. **Comparative study of *"Tuwo"* made from maize, sorghum and rice.** *Nat Sci* 2026,24(1):19-30]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature 03. doi:10.7537/marsnsj240126.03

Keywords: Gelatinization temperature; pasting property; minerals content; sensory attributes; starch content; *tuwo*

1.0 Introduction

Tuwo, a non-fermented maize dumpling is a popular diet native to Northern Nigeria where it is consumed by different tribes including the Hausas, Fulanis, Kanuri and Nupes. Popularity of Tuwo has increased as Yorubas of the South West Nigeria and some other West African countries including Ghana, Togo, Benin, Mali and Burkina-Faso are now embrassing it (Bolade & Moriamo, 2006). The food product is normally prepared from non-fermented cereal flour while its preparation and consumption have now been spread to other non-Hausa-speaking communities of West Africa due principally to inter ethno-tribal movement of people within the region (Bolade *et al*., 2002). The quality attributes normally used by the consumers for assessing tuwo are colour (white to creamy), texture (ease of mouldability and swallowability) and pleasant taste (Bolade *et al*., 2009).

Maize is a good source of carbohydrates, fats, proteins and some of the important vitamins as well as minerals. It is also the richest in energy among cereal grains, and this is why it is been referred to as nutria-cereal (Kaul *et al.*, 2019). Maize (*Zeamays*) is an important food crop providing about 30 % of the calories for approximately 4.5 billion peoples in 94 developing countries (Kaul *et al.*, 2019). It is one of the most widely utilized cereals in Nigeria and other West African countries due to its high yielding potentials, storability and versatility in processing. Sorghum (*jowar*) tropical drought-tolerant crop packed full of nutrients- enriched with the goodness of protein, iron, and fiber, a good source of Vitamin B_6, magnesium, phosphorous help in reducing cholesterol levels as it has a component called policosanols (Ajanaku *et al*., 2012). Sorghum grains contain high fibre, starch and non-starchy polysaccharides with some unique characteristics. Protein quality and essential amino acid profile of sorghum is better than many of the cereals and is rich source of B-complex vitamins (Bagirei *et al*., 2022).

Rice is a food crop of world-wide importance and forms the foundation of the diet of over 3 billion people, constituting over half of the world's population. It is widely cultivated throughout the world and has become the second most important cereal in the world after wheat in terms of cultivation, due to a recent decline in maize production (Adekoyeni *et al.*, 2023). Rice (O*ryza sativa*) is an important convenience food for urban consumers Nigeria and much of sub-Saharan Africa. Among cereals in Nigeria, the per capita consumption of rice is second to maize (Quaye *et al.*, 2000). Consumption of rice in Nigeria has increased tremendously over the last few years and this is mainly as a result of increased urbanization and the relative ease with which it can be cooked (MoFA, 2005). *Tuwo* texture preference depends to a large extend on individual choice and community practice. However, people generally tend to prefer non-sticky tuwo with moderate hardness. The gel should be stiff, but not dense. A person should be able to dip in his fingers, scoop out a piece and readily manipulate the piece with the forefingers and thump without the gel adhering to the fingers (Bagirei *et al*., 2022). The taste of tuwo, the colour, depends on the grain from which it is prepared and the method of flour preparation which would determine the consumer acceptability. Hence, this research work examines the comparative study of tuwo made from maize, sorghum and rice flours singly.

2.0 Materials and Methods

2.1 Source of Materials

Maize, rice and sorghum used for this project were purchased from Owode Market in Offa, Offa Local Government, Kwara State, Nigeria.

2.1.2 Sample preparation

Preparation of tuwo flour

This was achieved according to the method of Bolade and Adeyemi (2012). This was done by initially cleaning the selected cereals grains (rice, sorghum and maize) singly manually by the removal of stones, damaged kernels and other extraneous materials. The grains were finally milled singly to obtain flour followed by sieving using a sieve with 300 μm aperture and then kept in airtight polythene bags until needed.

2.1.2 Preparation of Tuwo

Tuwo was prepared from each flour sample using a method as described by Bolade *et al.* (2002); however, with slight modification. The overall ratio of flour to water used in the tuwo production was 1:3.5 w/v. Cold slurry of the flour was first prepared by mixing 60 % of the desired quantity of flour (1.0 Kg) with 25 % of the desired quantity of water (3.5 liter) to form slurry @ room temperature (28.0 ± 2.0 ºC). This was followed by bringing 60 % of the water into boiling and slurry initially prepared was added to this boiling water coupled with vigorous stirring using a wooden flat spoon, to form a pap-like consistency. The remaining quantity of the flour (40 % of the desired total) was then added gradually to the boiling pap-like paste with continuous stirring so as to facilitate non-formation of lumps and to ensure a homogenous gel formation. The remaining quantity of water (15 % of the desired total) was finally added to the formed gel, covered properly without stirring and allowed to cook for about 2 min after which it was removed from fire and stirred vigorously to ensure smoothness of the gel. The final product so obtained is called tuwo.

2.2 Methods of analysis

2.2.1 Proximate analysis

The standard method described by Association of Official Analytical Chemists, AOAC (2010) was used for proximate composition of the sample was carried out to quantitatively to determine the moisture, crude protein, fat, crude fibre, ash while carbohydrate content of the samples were determined by differences according to AOAC (2010). Chemical analysis such as total starch, amylose content and beta-carotene of the samples according to AACC (2000) while carbohydrate content was determined by difference.

2.2.2 Determination of functional properties of the *Tuwo* varieties flour samples

The functional properties (bulk density, water and oil absorption capacity, emulsion activity and stability) of the maize varieties flours samples were determined as described by Yasumatsu et al. (1972). Foaming capacity was evaluated using the method of Narayana and Narasinga (1982) while swelling power and solubility capacity were analyzed by the methods of Ukpabi and Ndimele (1990). Dispersibility was determined by the methods described by kulkarni et al. (1991) while gelatinization temperature was determined by the method described by Shinde (2001).

2.2.3 Determination of sensory evaluation of the *Tuwo* varieties cooked dough samples

Sensory attributes of the maize varieties flour samples were determined using preference test as described by Akinsola *et al*. (2018). Twenty semi-trained panelists that was familiar with *moin-moin* and *ekuru* puddy, a similar steaming product to the study samples were drawn from the Polytechnic community. The panelists were asked to indicate their preference for the samples in term of colour, appearance, mouldability, flavour, taste and overall acceptability on 9-point H The prepared samples were evaluated for sensory parameters which include colour, aroma, texture, taste and overall acceptability on a 9-point Hedonic scale where 9 =like extremely and 1=disliked extremely. Twenty panelists were used for the exercise. These panelists were selected among students both within and outside the department of Food Technology, Federal Polytechnic Offa, Kwara State especially those who are familiar with the product. Each panelist sat in an enclosed cubicle designed for sensory evaluation and water was provided to rinse mouths before and after tasting each of the samples.

2.2.4 Pasting Properties

Pasting properties was determined with a Rapid Visco Analyzer (RVA). Five grams (5 g) of each sample was weighed into a dried empty canister, and then 5ml of distilled water was dispensed into the canister containing the sample. The slurry was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50 - 95 ºC with a holding time of 2 min followed by cooling to 50 ºC with 2 min holding time. The rate of heating and cooling was at 22.5 ºC per min. Peak viscosity, trough viscosity, breakdown viscosity; final viscosity, setback viscosity, pasting temperature and peak time were read from the pasting profile with the aid of a thermocline for windows software connected to a computer (AACC, 2000).

3.0 Statistical Analysis

All analyses were conducted in duplicates. Data were subjected to analysis of variance, Duncan's multiple range tests was used to separate the means. SPSS software version 20 was used for all statistical analyses.

4.0 Results and Discussions

Table 1: Proximate composition of tuwo flour produced

Parameter	TML	TRL	TSL
Moisture	11.34±0.34^{a}	15.67±0.01^{c}	14.32±0.01^{b}
Protein	11.63±0.01^{b}	9.53±0.01^{a}	9.53±0.01^{a}
Fat	2.34±0.01^{a}	2.47±0.01^{b}	2.59±0.01^{c}
Fibre	1.53±0.01^{a}	1.54±0.01^{a}	1.65±0.01^{b}
Ash	1.40±0.01^{b}	1.42±0.01^{b}	1.27±0.01^{a}
Carbohydrate	71.57±0.01^{c}	69.43±0.01^{a}	70.25±0.01^{b}

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at p<0.05. Sample TML - maize flour; Sample TSL - sorghum flour, Sample TRL - rice flour

4.1 Proximate composition of tuwo flour produced

Moisture content is an important quality attribute on which the shelf stability and microbial growth susceptibility of any food depend. The moisture content tuwo flour ranged from 11.34 - 15.67 % with sample TML (tuwo maize flour) having the least value (11.34 %) and sample TRL (tuwo rice flour) having the highest value (15.67 %). There is significant ($p<0.05$) difference existed between the samples. Iyabo *et al*. (2018) reported low moisture content 9.69 % for sorghum in a related study. The rice tuwo result obtained in this study is related to the previous work of Jocelyne *et al*. (2020), who reported moisture content of (10.70, 11.51, 11.57, 11.31 and 11.72 %) for wheat, maize, sorghum, millet, and fonio, respectively. Rajkumar and Selvakulasingam (2019) reported moisture content for beans (11.07 %), wheat (12.70 %), maize (12.05 %) and finger millet (14.07 %) which are within the range of values obtained in this research work. The moisture content of any food is an indicator of its water activity and is used as a measure of stability and vulnerability to microbial contamination (Musa *et al*., 2022). Food with high moisture content facilitates the growth of microorganisms which resulted in food spoilage, while low moisture content in food samples increased the storage periods of the food products (Rajkumar & Selvakulasingam, 2019).

Protein is the most important macronutrient necessary for growth and bodybuilding (Rajkumar & Selvakulasingam, 2019). The values of protein content obtained in this study vary from 9.53 - 11.63 %, with maize having the highest value (11.63 %), and rice and sorghum having the same value and are low in protein content (9.53 %). The values of crude protein reported here are slightly lower than 12.66 % reported by Iyabo *et al*. (2018) for unsprouted sorghum bicolar. In a related study, Rajkumar and Selvakulasingam (2019) studied the nutrient composition of some selected cereal grains available in Jaffna, Sri Lanka reported 15.23 %, 10.85 % and 9.19 % for wheat, maize and finger millet, respectively. However, Yankah *et al*. (2020) reported lower crude protein values of 4.28±0.19 for brown rice. The presence of high protein content found in maize tuwo in this study indicates that maize tuwo can be considered a good source of protein-rich food (Musa *et al*., 2022)

According to Akinoso and Adeyanju (2010), oil recovery and yield is dependent on solvent and method of extraction. Fat content was statistically varies from 2.34 - 2.59 %. Sample TML had the least value (2.34 %) and sample TSL had the highest value (2.59 %). The fat content in high fat content in sorghum indicate large deposit of oil in sorghum bran that may permit inward movement of fat and therefore increase the deposit of fat compared to other tuwo samples (Akinoso & Adeyanju, 2010). The fat content obtained is this study was lower to the 11.3 - 14.50 % of rice tuwo prepared using different processing method by Adekoyeni *et al*. (2023). Also, the result of 3.12 - 3.39 % by Adegbehingbe (2014) on masa produced from sorghum-maize was slightly higher than the values obtained in this present work

The crude fiber tells about the quantity of indigestible pentose, cellulose, lignin, and other constituents of this nature present in foods (Musa *et al*., 2022). As shown in Table 1, fibre content ranged 1.53 - 1.65 % with sample TML having the lowest value (1.53 %) and sample TSL having the higets value (1.65 %). The result shows insignificant difference between sample TML and TRL ($p<0.05$). The crude fibre content obtained in this study was lower than 2.03 % reported for unsprouted sorghum bicolar (Iyabo *et al*., 2018). The crude fibre values, 2.81 % (wheat), 6.69 % (maize), 8.14 % (sorghum), 3.89 % (millet) and 3.38 % (fonio) were reported by Jocelyne *et al*. (2020). The substantial high quantity of crude fiber obtained in the present study indicates that the tuwo produced are good sources of dietary fiber, which is vital for a good bowel movement and could help in the prevention of obesity, diabetes, colon cancer, and other ailments related to the gastrointestinal tract (Musa *et al*., 2022).

The ash content ranged from 1.27 - 1.42 % for sample TSL and TRL respectively. The ash content obtained for rice sample was slightly high compare to 0.99 % reported for 20 rice varieties (Iwe *et al*., 2016). The results agreed with the finding of Iyabo *et al*. (2018) who reported ash content values of unsprouted sorghum bicolar to be 1.47 %. Yankah *et al*. (2020) reported 0.79 % and 1.46 % for maize and millet, respectively. The variation in the ash content of samples in different studies may be due to the nature and amount of ions present in the soil from which plants draw their nutrients (Musa *et al*., 2022). Ash content is a nutritional component that reflects the total amount of inorganic matter or mineral composition of food.

Carbohydrates are one of the main sources of energy for the body (Musa *et al*., 2022). The values of the carbohydrate content in this study vary from 69.43 % (rice tuwo) to 71.57 % (maize tuwo). The carbohydrates content of millet, brown rice and maize according to Yankah *et al*. (2020), were reported to be 70.41 ± 1.00 %, 77.94 ± 0.32 % and 73.94 ± 0.51 %, respectively. Similarly, Kumar *et al*. (2016) reported carbohydrate content for brown rice, millet and maize to be 76.2 %, 67.5 %, and 74.3 %, respectively, which agreed with the present study. Generally, the present study showed that all the studied tuwo samples have appreciably high carbohydrate content.

Table 2: Selected mineral content of tuwo flour produced

Sample (mg/100g)	TML	TRL	TSL
Calcium, Ca	7.73±0.01[b]	7.39±0.01[a]	8.17±0.01[c]
Magnesium, Mg	4.66±0.01[c]	4.27±0.01[b]	4.05±0.01[a]
Potassium, K	6.14±0.01[a]	6.53±0.01[b]	6.79±0.01[c]
Manganese, Mn	4.93±0.01[b]	4.57±0.01[a]	5.01±0.01[c]
Zinc, Zn	4.39±0.01[c]	4.18±0.01[b]	3.85±0.01[a]
Iron, Fe	2.81±0.01[b]	2.64±0.01[a]	2.94±0.01[c]

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at $p<0.05$. Sample TML - maize flour; Sample TSL - sorghum flour, Sample TRL - rice flour

4.2 Mineral content of tuwo flour produced

The results of the analysis of selected mineral contents in some tuwo flour from maize, rice and sorghum is presented in Table 2. The calcium content ranged from 7.39 - 8.17 mg/100g. Calcium level of sample TSL was higher with 8.17 mg/100g while sample TRL was the lowest with 7.39 mg/100g. Calcium has been reported to helps muscle relaxation and contract, and very important in nerve functioning (Adeoti *et al*., 2013). Magnesium content ranged from 4.05 - 4.66 mg/100g. The highest is in sample TML with 4.66 mg/100g and the lowest is sample TSL 4.05 mg/100g. The result shows significant difference among the samples ($p<0.05$). Akande *et al*. (2018) reported 17.00 - 23.33 mg/100g for rice-based masa enriched with grain amaranth and carrot powder and 107.68 mg/100g for ogi made from soaked sorghum by Pikuda and Ilelaboye (2013) were all found to be higher than the values obtained in this study. Magnesium is required for making protein, boost immune system and muscle transmission (Morakinyo & Adegoke, 2016). The sample TML with the highest value will provide the body with RDA of magnesium if consumed adequately.

The potassium content ranged from 6.14 - 6.79 mg/100g with sample TSL having the highest value (6.79 mg/100g) while sample TML has the least value (6.14 mg/100g). The result shows significant difference between the samples ($p<0.05$). Potassium values obtained in this study is very low to 122.6 - 638.00 mg/100g by Akande *et al*. (2018) who work on rice-based *masa* enriched with grain amaranth and carrot powder. The finding of Pikuda and Ilelaboye (2013) showed high potassium content in soaked sorghum powder (134.93 mg/100g). Potassium is needed for proper fluid balance, nerve transmission and muscle contraction. Therefore, consumption of tuwo from sorghum flour may supply the needed potassium content to the body.

Manganese is an essential element found in various enzymes such as hydrolases, kinases, decarboxylases, and transferases. Insufficient intake of magnesium can lead to various health problems such as stunted growth, decreased reproductive function, abnormalities in the skeletal system, and issues with the metabolism of lipids and carbohydrates (Ikem *et al*., 2023). Mn concentrations across the tuwo sample were maximal in sorghum sample (5.01 mg/100) and lowest in rice (4.57 mg/100). The mean Mn concentration in this study was higher than 1.16 mg/100g reported in other published work (Ikem *et al*., 2023).

Zinc is an essential trace element that functions as a cofactor for certain enzymes involved in metabolism and cell growth (Cannas *et al*., 2020). Zn involved in the metabolism of proteins, carbohydrates, lipids and energy. It plays an important role in various biochemical pathways. The RDA for zinc is 8 mg/day for women, 11 mg/day for men and between 3 and 5 mg/day for children. Zinc content ranged 3.85 - 4.39 mg/100g. The highest concentration of Zn in this study was found in maize tuwo (4.39 mg/100g) and the lowest in sorghum (3.85 mg/100g). These values are higher than 0.83 mg (maize), 1.40 mg (sorghum) and 0.95 mg (millet) reported in another study (Jocelyne *et al*., 2020). Similarly, Yankah *et al*. (2020) reported the Zn content of maize, rice and millet to be 11.70 mg/100, 12.00 mg/100, and 11.30 mg/100, respectively. The high zinc content obtained in sample TML is an indication of a high content of zinc in the samples analyzed.

The results show that the concentration of iron ranged from 2.64 - 2.94 mg/100g with sample TRL having the least value and sample TSL having the highest value. The result shows significant difference between the samples ($p<0.05$). Iron is the most abundant metal in the human body. These values are lower than 2.92, 10.05 and 15.29 % for maize, sorghum and millet, respectively reported by Jocelyne *et al*. (2020) and 54.44 mg/100g for soaked sorghum powder ogi by Pikuda and Ilelaboye (2013). The values obtained here is greater than 0.14 - 0.35 mg/100g reported by Akande *et al*. (2018) for masa samples. Enough consumption of Iron will help to prevent impaired intellectual development in children, lead poisoning in children and prevent anaemia both in adults and children and help in the metabolism of all living organisms and humans (Akande *et al*., 2018).

Table 3: Starch and functional properties of tuwo flour produced

Sample (%)	TML	TRL	TSL
BD (mg/100g)	$0.74{\pm}0.01^{a}$	$0.75{\pm}0.01^{ab}$	$0.79{\pm}0.01^{b}$
WAC	$2.54{\pm}0.01^{b}$	$2.55{\pm}0.01^{b}$	$2.47{\pm}0.01^{a}$
Swelling capacity	$2.89{\pm}0.01^{b}$	$2.84{\pm}0.01^{a}$	$2.86{\pm}0.01^{ab}$
Swelling stability	$1.90{\pm}0.01^{b}$	$1.85{\pm}0.01^{a}$	$1.95{\pm}0.01^{c}$
Dispersibility	$74.00{\pm}0.01^{a}$	$76.00{\pm}0.01^{a}$	$73.00{\pm}0.01^{a}$
Gelatinization	$70.00{\pm}0.01^{b}$	$68.00{\pm}0.01^{ab}$	$64.00{\pm}0.01^{a}$

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at $p<0.05$. Sample TML - maize flour; Sample TSL - sorghum flour, Sample TRL - rice flour

4.3 Starch and functional properties of tuwo flour produced

Table 3 shows the functional properties of tuwo produced from maize, rice and sorghum. Bulk density result ranged 0.74 - 0.79 mg/100g with sample TML having the least value (0.74 mg/100g) and sample TSL having the highest value (0.79 mg/100g). The result shows insignificant variation between the samples ($p<0.05$). The result obtained in this study was similar to 0.89 - 0.97 g/cm^3 obtained in Bolade and Moriamo (2006) for tuwo produced from sorghum. Bulk density is a measure of the bulkiness of a flour sample. Jones *et al*. (2004) reported that bulk density is generally affected by the particle size and density of the flour and it is one of the essential parameter in determining the type of packaging material, handling and application in the food industry.

The water absorption capacity ranged 2.47 - 2.67 % for sample TSL and TML, respectively. Insignificant difference ($p<0.05$) was observed in sample TML and TRL. Similar value of this study was obtained in Olajide and Nsakpuma (2019) and in tuwo produced from grit non-soaking (2.31ml/g) and grit soaking (2.34ml/g) maize. The range obtained in this research work was high to that of 1.54 - 1.86 ml/g for pearl millet varieties by Pawase *et al*. (2021) but lower than 51.09 - 126.32 % by Umar *et al*. (2022) for kadal flour from whole and decorticated maize and millet. The value of 121.31 - 245 % recorded by Sunmonu *et al*. (2021) for maize-cassava starch tuwo was found to be higher than the values obtained in this present work. According to Seena and Sridha (2005), high water absorption causes high retention of water without dissolution of protein, thus increasing the body and viscosity of gel. Water absorption capacity is essentially a measure of the ability of the flour to associate with water, particularly in a food product where hydration is required in its preparation, so as to enhance its handling characteristics such as in doughs and pastries making. It has however been observed that the water absorption capacity of flour can be influenced by certain factors such as the particle size of the flour temperature of water and the quantity of hydrophilic constituents in the flour such as starch, protein and fibre (Sefa-Dedeh *et al*., 2003).

The swelling capacity of *tuwo* maize varieties under this study ranged from 2.84 - 2.89 % for sample TRL and TSL sample, respectively. The result shows no statistical variation between the samples ($p<0.05$). The variations in the swelling capacity of different forms of *tuwo* flour under this study may be due to the difference in seed volume. Swelling capacity value obtained in this research work was low compared to (4.00 - 6.00 ul/seed) obtained for varieties of millet as reported by Pawase *et al*. (2021). The previous work of Sunmonu *et al*. (2021) reported (594.21 - 888.78 %) of *tuwo* made from maize-cassava starch. Olajide and Nsakpuma (2019) show that swelling capacity content ranged from (5.44 - 5.85 g/ml) for *tuwo* made from maize and baoba pulp flour which was higher to the ranged obtained in this research work. Swelling capacity is regarded as a quality criterial in some food formulations. It is an evidence of non-covalent bonding between molecules within starch granules and ratio of α-amylose and amylopectin activities. Swelling power is an indication of the extent of associative forces within the granule and it is also related to the water absorption index of starch-based flour during heating.

The results of swelling index of the *tuwo* flour ranged from 1.85 - 1.95 % with sample TRL (rice tuwo) having the least value (1.85 g/g) and sample TSL (sorghum tuwo) having the highest value (1.95 %). The value obtained (0.26 - 0.50 %) for varieties of millet by Pawase *et al*. (2021) was low to the values obtained in this research work. swelling index is an indication of the noncovalent bonding between the molecules of starch granules and on the factors of αamylose and amylopectin ratios (Iwe *et al*., 2016). The swelling index of flours is influenced by the particle size, species variety and method of processing or unit operations (Suresh & Samsher, 2013).

Gelatinization temperature of all the flour samples investigated fell within ranged 64.0 - 70.0 ºC). The result shows that sample TSL had the lowest value (64.0 ºC) while sample TML had the highest value (70.0 ºC). There was significant variation between the samples ($p<0.05$). Result (62.0 - 65.3 ºC) of Bagirie *et al*. (2022) of *tuwo* from sorghum-cowpea and millet-cowpea was within the ranged values obtained in this present work. Gelatinization temperature is the temperature at which starch molecules in a food substance lose their structure and leach out from the granules as swollen amylose and it affects the time required for the cooking of food substances (Eleazu *et al*., 2014).

Dipersibility value ranged from 73.0 - 76.0 %. It was observed that sample TSL had the least value (73.0 %) while sample TRL had the highest value (76.0 %). The result shows significant variation between the samples ($p<0.05$). The result obtained in this research work was within the range value (70.5 - 77.0 %) for kadal flour from whole and decorticated maize and millet in research work of Umar *et al*. (2022). The starch contents of the flours ranged between 69.4 and 76.1 %. The result showed that sample produced from maize flour (sample TML) had the highest value (76.1 %) while sample produced from sorghum fllour (sample TSL) had the least value (69.4 %). The result shows significant variation between the samples ($p<0.05$). The differences in the value obtained may be due to different cereal used, environmental condition. Starch has been reported to determine the physiocochemical, rheological and textural characteristics of food products.

Table 4: Pasting properties of tuwo flour produced

Sample (RVU)	TML	TRL	TSL
Peak	381.21±0.01^c	369.21±0.01^b	333.10±0.01^a
Trough	187.21±0.01^c	151.91±0.01^b	138.01±0.01^a
Breakdown	152.31±0.01^c	124.11±0.01^b	110.61±0.01^a
Final	311.21±0.01^c	253.21±0.01^b	218.21±0.01^a
Setback	172.51±0.01^c	154.61±0.01^b	143.61±0.01^a
Time (min)	5.10±0.01^a	5.30±0.01^a	5.15±0.01^a
Temperature (ºC)	83.66±0.01^a	84.51±0.01^c	84.36±0.01^b

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at $p<0.05$. Sample TML - maize flour; Sample TSL - sorghum flour, Sample TRL - rice flour

4.4 Pasting properties of tuwo flour produced

The pasting properties of the tuwo flour are as shown in Table 4. When heat is applied to starch-based foods in the presence of water, a series of changes occur known as gelatinization and pasting. Pasting property is one of the most important properties that influence quality and aesthetic consideration in the food industry since they affect texture and digestibility as well as the end use of starch-based food commodities (Ajanaku *et al.*, 2012). It is an index for predicting the ability of a food to a paste when subjected to heat applications. Peak viscosity is the maximum viscosity developed during or soon after the heating begins. It is an index of the ability of starch-based foods to swell freely before their physical breakdown (Adebowale *et al.*, 2008) and this explains why tuwo flour produced in this research work ranged from 333.1 - 381.2 RVU with sample TSL having the least value (333.1 RVU) and sample TML having the highest value (381.2 RVU). The result shows significant difference between the samples ($p<0.05$). High peak viscosity is an index of high starch content and also reflects fragility of the swollen granules which first swell and then breaks down under the continuous mixing of the rapid Visco Analyzer. The high peak viscosity values obtained in this study is of processing advantage and has been reported to be significant in the preparation of stiff dough products like tuwo, a stiff dough product made from cereal flour and eaten with stew and vegetable (Danbaba *et al.*, 2014; 2012).

Trough viscosity is the minimum viscosity value in the constant temperature phase of the rapid visco analyzer pasting profile. The result obtained for trough was 138.0 - 187.2 RVU. Sample TML had the highest value while sample TSL had the least value. There was a significant difference ($p<0.05$) in the trough viscosity of the flour varieties. In simple terms, trough viscosity is the point at which the viscosity reaches its minimum during either heating or cooling processes. It measures the ability of the paste to withstand breakdown during cooling. The significantly high trough viscosity observed in this study indicates the tendency of the rice flour to breakdown during cooking. The values obtained in this study are lower compared to the range of 1017-3000 RVU obtained for cassava-African yam bean flour blends as reported by Abioye *et al*. (2022).

The breakdown viscosity of rice flour ranged from 110.6 - 187.2 RVU. Sample TML had the highest value of (187.2 RVU) while sample TSL had the least value (110.6 RVU). The differences in the value may be due to the differences in their varieties. A lower breakdown value indicates relative paste stability during cooking while a higher value indicates relative paste instability. The results obtained in this research work are within the range value of 42 50 - 266.50 RVU by Abioye *et al*. (2022). Adebowale *et al.* (2005) reported that the higher the breakdown viscosity, the lower the ability of the flour to withstand heating and shear stress during cooking. Result obtained on the physicochemical properties of tuwo flours showed that the cultivar with the highest breakdown viscosity was the most palatable.

Final viscosity ranged 218.2 - 311.2 RVU with sample TSL having the least value (218.2 RVU) and sample TML having the highest value (311.2 RVU). There was a significant difference in the final viscosity of the varieties of the flours ($p<0.05$). The result obtained in this research work was very low to 1276.0 - 3985.0 RVU reported by Abioye *et al*. (2022). The final viscosity values obtained in this study are higher than the range value (73.3 - 22.8 RVU) obtained by Iwe *et al.* (2016) who work on proximate, functional and pasting properties of Faro 44 rice, African yam bean and brown cowpea seeds composite flour. Final viscosity is commonly used to define the quality of particular starch-based flour since it indicates the ability of the flour to from a viscous paste after cooking and cooling. It also gives a measure of the resistance of the paste to shear force during stirring. The variations in the final viscosity might be due to the simple kinetic effect of cooling on viscosity and the reassociation of starch molecules in the flour samples. This may be attributed to the hydrogen bonding during cooling and high amylose content of the rice flour.

There was a significant different in the setback viscosity of the tuwo flour samples whose content ranged from 143.6 - 172.5 RVU for sample TSL and TML, respectively. The higher the setback viscosity, the lower the retrogradation of the flour paste during cooling and the lower the staling rate of the products made from the flour. The setback value obtained in this research work was lower compared to 370.5 - 897.0 RVU reported by Abioye *et al*. (2022). Setback viscosity has been correlated with the texture of various end products. Setback viscosity indicates the tendency of starch granules to retrograde on cooling.

Peak time is a measure of the cooking time and it ranged from 5.25 - 5.30 min for sample TSL and TML, respectively. Peak time values reported in this work are similar to the peak time values of 5.13 - 5.80 min and 5.0 to 6.30 min reported for instant yam- breadfruit composite flour and germinated tigernut flour, respectively (Adebowale *et al.*, 2008). The value of 5.85 - 7.00 min obtained by Abioye *et al.* (2022) who work on chemical composition, nutritional, functional and pasting properties of yellow root cassava grits and African yam bean flour blends was slightly higher than the values obtained in this study. Peak temperature ranged from 83.66 - 84.51 ^{o}C with sample TML having the least value (83.66 ^{o}C) while sample TRL has the highest value (84.51 ^{o}C). The result shows significant difference between the samples ($p<0.05$). The value obtained in this research work is similar to the value of 74.58 - 84.80 ^{o}C by Abioye *et al*. (2022).

Table 5: Sensory evaluation of tuwo produced

Samples	TSL	TML	TRL
Colour	7.8±0.11^{ab}	7.6±0.02^{b}	7.2±0.01^{a}
Aroma	7.6±0.02^{b}	8.0±0.01^{c}	7.3±0.00^{a}
Taste	7.9±0.00^{b}	7.8±0.02^{ab}	7.6±0.03^{a}
Texture	8.0±0.03^{c}	7.7±0.01^{b}	7.1±0.00^{a}
Overall acceptable	7.6±0.02^{b}	8.1±0.00^{c}	7.3±0.03^{a}

Results are mean values of duplicate determination ± standard deviation. Mean value within the same row having the same letter are not significantly different at $p<0.05$. Sample TML - maize flour; Sample TSL - sorghum flour, Sample TRL - rice flour

4.5 Sensory evaluation of tuwo produced

Sensory evaluation of tuwo produced from maize, rice and sorghum revealed that colour parameter ranged from 7.2 – 7.8 with sample TSL (sorghum tuwo) having the highest value and sampleTRL (rice tuwo) having the least value. The high percentage score obtained in sample TSL could be as a result of red pigment of its colour. Aroma mean score ranged from 7.3 - 8.0 for sample TRL and TML, respectively. Taste mean score ranged from 7.6 – 7.9 with sample TSL having highest and sample TRL lowest. Texture result of tuwo produced ranged from 7.1 - 8.0 for sample TSL and TRL, respectively. Overall acceptability ranged from7.3 - 8.1 for sample TRL (rice-tuwo) and sample TML (maize-tuwo), respectively. The result shows that the three tuwo meals produced were acceptable but tuwo produced from maize flour was most preferred. The score obtained from the panelists preference on tuwo made from maize flour could be as a result of their familiarity with the tuwo produced from maize.

5.0 Conclusion

Study showed the nutritional and chemical variation that exists in samples of selected varieties of cereals (sorghum, rice and maize) in the production of tuwo. Result shows that nutritional and minerals properties of yellow maize produced tuwo are richer than sorghum and rice produced tuwo. Water absorption capacities results showed the extent to which water can be added during dough preparation using the various flour samples. The utilization of Nigeria locally available cereals in producing our local food should be imposed in order to improve the utilization of those cereals while further research could be done on colour parameter, textural properties of this research work.

Funding and conflict of interest

There was no direct funding for the research, and authors declare no conflict of interest. The project was self-funded by the authors.

Correspondence address

Akinsola, Akinjide O. PhD
Department of Home Economics
Federal College of Education (Special)
P.M.B. 1089, Oyo, Oyo State, Nigeria.
email: Akinsola.akinjide1333@fcesoyo.edu.ng

References

1. Abioye, V.F., Olodude, O.A., & Akinwande B.A. (2022). Chemical Composition, Nutritional, Functional and Pasting Properties of Yellow Root Cassava Grits and African Yam Bean Flour Blends. *International Journal of Food Studies, 11*, 71–84.
2. Adebowale, A.A., Sanni, L.O., Onitilo, M.O. (2008). Chemical composition and pasting properties of tapioca grits from different cassava varieties and roasting methods. *Afr. J. Food Sci.*, *2*, 77-82.
3. Adebowlae, A.A., Sanni, L.O., & Awonarin, S.O. (2005). Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. *Food Science and* Technology *I*nternational, *11*, 373-382.

4. Adegbehingbe, K.T. (2013). Microbiological and nutrient studies of fermented cooked Lima beans (Phaseoluslunatus). *Global J. Biol. Agric. Health Sci. 2*, 94-101.
5. Adekoyeni, O.O., Umar, H.A., Adegoke, A.F., & Salako, S.G. (2023). Effect of variety and processing methods on nutrients retention of tuwo (mashed rice) prepared from rice. *Nigerian Journal of Horticultural Science. 27(4)*, 37 – 48.
6. Adeoti, O.A., Elutilo, O.O., Babalola, J.O., Jimoh, K.O., Azeez, I.A., Rafiu, K.A. (2013). Proximate, mineral, amino acid and fatty acid compositio of maize tuwo –cirina florida flour blends. *Journal of Biological Science. 3*,165-171.
7. Ajanaku, K.O,, Ajanaku, C.O., Edabor-Osoh, A., & Nwinyi, O.C. (2012). Nutritive value of sorghum ogi fortified with groundnut seed (*Arachis hypagoea L.*). *American Journal of Food Technology. 7*, 82-88.
8. Akande, O.A., Jolayemi, O.S., Familusi, A., & Idowu B. (2018). Nutritional, antioxidant and sensory properties of rice-based *masa* enriched with grain amaranth and carrot powder. *Annals.Food Science and Technology, 19*(4), 124 - 133.
9. Akinoso, R., & Adeyanju, J. A. (2010). Optimization of edible oil extraction from ofada rice bran using response surface methodology. *J. Food and Bioprocess Technology* DOI:10.1007/s11947-010-0456
10. Akinsola, A., Segilola, V., Oloso, S. & Durojaiye, O. (2018). Quality evaluation of plantain-African yam bean flour blends and sensory properties of its cooked (amala) paste. *Research Journal Food Science and Nutrition, 3*, 31-40.
11. American Association of Cereal Chemists (AACC). (2000). Approved Methods of the American Association of Cereal Chemists. Official Methods of Analysis. 10th Edition, AACC International, USA, St. Paul, MN,54-21(1).
12. Association of Official Analytical Chemists (AOAC) (2010). Official method of analysis, 18th ed., Washington DC.
13. Bagirei, S.Y., Iro-Nkamaσ, M.H., Badau, P. & Idakwo, P.Y. (2022). Production of *Tuwo* from sorghum-cowpea and millet-cowpea composite flours: Assessment of flour quality parameters and the textural properties and acceptability of *Tuwo*. *London Journal of Engineering Research*, 22(7). Compilation 1.0449U London.
14. Bolade, M.K. & Adeyemi, I.A. (2012). Functionality enhancement of composite cassava flour in the production of maize tuwo (a nonfermented maize-based food dumpling). *Food Bioprocess Technol, 5*, 1340–1348.
15. Bolade, M.K., Adeyemi, I.A., & Ogunsua, A.O. (2009). Influence of particle size fractions on the physicochemical properties of maize flour and textural characteristics of a maize-based non fermented food gel. *International Journal of Food Science and Technology, 44*, 646–655.
16. Bolade M.K., & Moriamo S.B (2006). Textural and sensory quality enhancement of sorghum tuwo. *International Journal of Food Science and Technology, 41(2)*, 115–123.
17. Bolade, M.K., Usman, M.A., Rasheed, A.A., Benson, E. L., & Salifou, I. (2002). Influence of hydrothermal treatment of maize grains on the quality and acceptability of tuwon masara (traditional maize gel). *Food Chemistry, 79*, 479–483.
18. Cannas, D., Loi, E., Serra, M., Firinu, D., Valera, P., & Zavattari, P. (2020). Relevance of essential trace elements in nutrition and drinking water for human health and autoimmune disease risk. *Nutrients, 12, 7*, 2074. doi:10.3390/ nu12072074.
19. Danbaba, N., Ukwungwu, M.N., Maji, A.T., Ndindeng, S.A., Jiya, A.G., Danfulani, S., & Onyeneke, E.N. (2014). End-use quality of upland Nerica rice (Oryza sativa L) as affected by the addition of sweet cassava (Low cyanide, Manihotesculenta) flour. *International Journal of Agriculture and Forestry, 4(3)*, 237-245.
20. Danbaba, N., Anounye, J.C., Gana, A.S., Abo, M.E., Ukwungwuu, M.N., & Maji, A.T. (2012). Physical and pasting properties of

ofada rice (*Oryza sativa L*) varieties. *Nigerian Food Journal, 30,* 18-25.

21. Eleazu, O.C., Eleazu, K.C., & Kolawole, S. (2014). Use of indigenous technology for the production of high quality cassava flour with similar food qualities as wheat flour. *Acta Sci Pol Technol Aliment, 13,* 249-256.
22. Ikem, A., Odumosu, P. O., & Udousoro, I. (2023). Elemental composition of cereal grains and the contribution to the dietary intake in the Nigerian population. *Journal of Food Composition and Analysis, 118,* 105207, https://doi.org/10.1016/j.jfca.2023.105207
23. Iwe, M.O., Onyeukwu, U., & Agiriga, A.N. (2016). Proximate, functional and pasting properties of Faro 44 rice, African yam bean and brown cowpea seeds composite flour. Food Sciecne and Technology/research article.
24. Iyabo, O., Ibiyinka, O., & Abimbola, D.O. (2018). Comparative study of nutritional, functional and anti-nutritional properties of white sorghum bicolor (Sorghum) and Pennisetum glaucum (Pearl Millet). *International Journal of Engineering Technologies and Management Research, 5(3),* 151-158.
25. Jocelyne, R.E., Béhiblo, K., & Ernest, A.K. (2020). Comparative study of the nutritional value of wheat, maize, sorghum, millet, and fonio: some cereals commonly consumed in Cote d'Ivoire. *European Science Journal, 16(2),* 118-131.
26. Jones, D.M., Trim, D.S., Bambridge, Z.A., & French, L. (2004) Influence of selected process variables on the elimination of cyanide from cassava. *Journal of the Science of Food and Agriculture, 66,* 535-542.
27. Kaul, J., Jain, K. & Olakh, D. (2019). An overview on role of yellow maize in food, feed and nutrition security. *International Journal of Current Microbiology and Applied Science. 8(2).* 3037-3048.
28. Kulkarni, K.D., Kulkarni, D., & Ingle, U. (1991)."Sorghum malt-based weaning food formulations: preparation, functional properties, and nutritive value". *Food and Nutrition Bulletin, 13,* p. 17.
29. Kumar, A., Metwal, M., Kaur, S., Gupta, A. K., Puranik, S., Singh, S., ….. ,. & Sood, S. (2016). Nutraceutical value of finger millet [Eleusine coracana (L.) Gaertn.], and their improvement using omics approaches. Frontiers in plant science, 7, 934. https://doi.org/10.3389/fpls.2016.00934.
30. MoFA. (2005). Agriculture in Ghana - Facts and figures, Policy Planning, Monitoring and Evaluation (PPMED). Ghana: Ministry of Food and Agriculture.
31. Morakinyo, A.O., Samuel, T.A., Adegoke, O.A. (2016). Mineral composition of commonly consumed local foods in Nigeria. *Afr J Biomed. Res., 19,* 141-147.
32. Musa, O.S., Chadi, A.S., Saidu, U., & Daniel, O.O. (2022). Proximate and elemental analysis of dried watermelon (Citrullus lanatus) seeds. *SLU Journal of Science and Technology, 3(1, 2),* 16-22.
33. Narayana, K ., & Narasinga-Rao, M. (1982)." "Functional properties of raw and heat processed winged bean (Psophocarpus tetragonolobus) flour". *Journal of Food Science, 47,* 1534-1538.
34. Olajide, E.A., & Nsakpuma, T. (2019). Functional properties of maize flour (Zea mays) and stability of its paste (*tuwo*) as influenced by processing methods and baobab (Adansonia digitata) pulp inclusion. Food Technology, Federal University Wukari, Wukari, Nigeria.
35. Pawase, P.A., Chavan, U.D., & Kotecha, P.M. (2021). Evaluation of functional properties of different pearl millet cultivars. *The Pharma Innovation Journal, 10(6),* 1234-1240.
36. Pikuda, O.O., & Ilelaboye, N.O. (2013). Proximate and chemical composition of *Ogi* prepared from whole and powdered grains (Maize, Sorghum and Millet). *Scholars Research Library Annals of Biological Research, 4(7),* 239-242.
37. Quaye, W., Greenhalgh, P., Manful, J., & Hammond, L. (2000).Rice parboiling in Ghana - a socio-economic survey, NRI

Report No. 2577. Natural Resources Institute, University of Greenwich, UK, p. 54.

38. Rajkumar, G., & Selvakulasingam, B. (2019). Comparative study of nutrient composition of selected cereal grains available in Jaffna, Sri Lanka. *Annals of Biological Research, 10(2)*, 21-24.
39. Seena, S., & Sridhar, K.R. (2005). Physiochemical, functional and cooking properties of under explored legumes, Canavalia of the Southwest coast of India. *Food Research International*, *38,* 803 – 814.
40. Sefa-Dedeh, S., Cornelius, B., & Afoakwa, E.O. (2003). Effect of fermentation on the quality characteristics of nixtamalized corn. *Food Research International*, *36,* 57–64.
41. Shinde, B.G. (2001). Isolation and characterization of starch horse grain." Rahuri (India)". Unpublished M.Sc Thesis, Mahatma Phule Krishi Vidyapeeth.
42. Sunmonu, B., Akinsola, A.O., Ayanlola, B. T., Obisesan, D.O., & Taiwo-Oshin, M.A. (2021). Production and quality evaluation of "*Tuwo*" (A cooked paste of non fermented whole maize flour) made from maize and different cassava adjuncts. *Nature and Science, 19(11)*, 21-29.
43. Suresh, C., & Samsher, C.O. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research, 8(38)*, 4849-4852.
44. Umar, B.H., Agbara, G.I., Alkali, M.Y., Masaya, A.F., & Akubuiro, S.C. (2022). Proximate composition, functional, and sensory properties of kadal (fermented grain flour) produced from whole and decorticated maize and pearl millet grains, *AZOJETE*, 18(2), 345–356.
45. Ukpabi, U., & Ndimele, C. (1990). Evaluation of the quality of gari produced in Imo state. *Nigerian Food Journal*, *8*, 105-110.
46. Yankah, N., Intiful, F.D., & Tette, E.M. (2020). Comparative study of the nutritional composition of local brown rice, maize (obaatanpa), and millet. A baseline research for varietal complementary feeding. *Food Science and Nutrition*, *8(6)*, 2692-2698.
47. Yasumatsu, K., Sawada, K., Moritaka, S., Misaki, M., Toda, J., Wada, T. & Ishii, K. (1972). Whipping and emulsifying properties of soybean products". *Agricultural and Biological Chemistry*, *36*, 719-727.
48. Yellavila, S.B., Agbenorhevi, J.K., Asibuo, J.Y., & Sampson, G.O. (2015). Proximate compoxition, mineral content functional properties of five liman accessions. *J. of Food Security*, *3(3)*, 69-74.