Original Research Article

PHYSICO-CHEMICAL PROPERTIES OF FLOURS FROM FIVE YAM VARIETIES GROWN IN BENUE STATE NIGERIA

ABSTRACT

Reduction of post-harvest losses of Benue yams birthed this research. The study investigated the functional, pasting properties and nutritional composition of high quality flours produced from five Yam varieties grown in Benue State, Nigeria. Their functional properties: Bulk density, Dispersibility, Water absorption capacity, Oil absorption capacity, Swelling index and Swelling capacity ranged from 0.70-0.84 g/cm^3, 23.17-39.33g/mL, 0.87-2.53mL/g, 0.93-2.03mL/g, 0.92-2.07mL/g and 146.30-265.82%. Pasting properties: Peak viscosity, Trough, Breakdown, Final Viscosity, Set back, Peak time and Pasting temperature, ranged from 1285.00-4586.33RVU,1102.00-4035.00RVU,57.07-1046.00RVU,1878.33-6428.00RVU, 688.00-2393.33RVU, 5.40-7.20Mins and 81.50-88.85°C. Proximate parameters: Moisture content, Ash, Crude fiber, Protein, Fat, Carbohydrates and Energy values ranged from 7.61-9.70%, 0.05-3.80%, 0.10-4.82%, 7.77-9.27%, 1.19-1.51 %; 75.09-79.55% and 326.50-343.52kcal. Vitamins: A, C, E, D, K and B ranged from 0.66.41-807.55mg/100g, 08.73-27.02mg/100g, 0.08-1.24mg/100g, negligible in all samples, 0.12-0.74mg/100g and 0.73-0.83. Minerals:Sodium(Na),Potassium(K),Calcium(Ca),Magesium(Mg),Phosphorus(P),Manganese (Mn) and Zinc(Zn):ranged from 47.42-59.73 mg/100g, 69.01-123.51mg/100g, 25.28-33.01mg/100g, 39.18-58.02mg/100g, 0.04-0.12mg/100g, 2.95-5.43mg/100g and 0.79-1.25mg/100g respectively. Results revealed that, the physico-chemical properties of the high quality yam flours compared favorably with the standard wheat flour (control), therefore, they exhibited good qualities of flours for baking of confectioneries.

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Keywords: Functional properties; Pasting properties; Nutritional composition; Confectioneries, Post-harvest losses.

1. INTRODUCTION

Huge post-harvest losses of yams is painfully a recurring experience of stakeholders in Nigeria, particularly Benue State which produces yams in largest quantities. Most of the yams annually produced are wasted or lost through sprouting, respiration/transpiration leading to rottenness, weight and quality losses of the yam tubers and spoilage due of lack of post-harvest facilities like storage and processing equipment in the country (Shambe, 2017). Yams; member of the monocotyledonous family (Dioscoreaceae) are annual root tuber bearing plants with over 600 species. From these; ten are communally and economically important in terms of food, cash and medicine and are favorite staple foods predominantly in Benue State (Joy & Siddhuraju, 2017). Nigeria produces yams in huge quantities, but ninety-five percent of it; is consumed internally in limited value forms. So, though, Yams have great prospective for industrialization,

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Nigeria continues to import starch, flour, sweeteners and adhesives that can be made from yams. Hence, despite the importance of yams to Nigerians as a component for justifiable food security; the readiness to its maintainable production and industrial development is still uncertain (Verter & Bečvařova, 2015). Thus, the urgency to promote increased utilization of the locally, readily available Yams, reduce their postharvest losses by transforming highly perishable Yam tubers at harvest into shelf stable products cannot be over-emphasized. This can be achieved by transformation of the yam tubers into yam flours to be used for processing of confectioneries like biscuits, cookies, cakes, etc (Oyeyinka *et al.*, 2017). Therefore, this research explored the potential of producing high grade quality flour for production of confectioneries from five yam varieties in Benue State, Nigeria.

2. MATERIALS AND METHODS

2.1 Yam tubers   'Raw materials' is more appropriate as sub- heading

purchased

Five varieties of Yams were purchase from Ukum Local Government area of Benue state in the month August 2022. They included Ogoja, Faketsa, Hembankwase, Amura (Discorea rotundata) and Gwebe(Water yam - Discorea alata). The yam samples were authenticated by an experienced botanist (- J. I. Waya) from the Department of Biological Sciences, Benue State University - Nigeria.

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2.2 Method   Add 'of production of flours'

Flours from the yams were produced using method of Oluwole *et al.*, (2013) with slight modification as shown in figure 1.

Yam tubers

↓

Sorting

↓

Washing

↓

Peeling

↓

Washing

↓

Slicing (2-3 mm thick)

↓

Sulphating (0.5 %, 3 min)

↓

Draining

↓

Blanching (98 °C, 5 min)

↓

Oven drying (60 °C, 24 h)

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Figure 1. Flow Chart for Production of Yam Flours.
Source: (Oluwole *et al*., 2013).

2.3 Analyses

You may add ' Physico-chemical' analysis

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2.3.1 Functional properties of the flours

Functional properties were determined as described by the standard methods of AOAC, (2012).

Please list the properties investigated here

2.3.2 Pasting Properties of the flours

Pasting properties were assessed using the Rapid Visco-Analyser (ModelRVAseries4; Newport Scientific Pty Ltd., Warriewood, Australia) as described by (Oluwole *et al*., 2013).

A list of the properties will be better

2.3.3 Proximate Analysis of the flours.

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Proximate composition was determined using AOAC, (2012) methods. Carbohydrate was calculated by difference. Energy content of the flours were determined using attwater factor as shown in equation 1.

Kindly List the parameters investigated in proximate analysis

$$Energy\ (kcal/100\ g) = 4 \times \%Protein + 9 \times \%Fat + 4 \times \%Carbohydrate \quad (1)$$

2.3.4 Vitamin content of the flours.

The methods AOAC,(2012) were used to determine vitamins A, B_1, C, D, E and K.

2.3.5 Mineral content of the flours

Kindly list the minerals here

Mineral contents were determined using the standard methods described by the AOAC, (2012).

3. STATISTICAL ANALYSIS

Determinations were carried out in triplicate. Results are presented as mean value ± standard deviation and analyzed by analysis of variance (ANOVA) using SPSS software package vision 26. Significant differences between means were determined by Duncan multiple range test (DMRT) at 95 % confidence limit.

4. RESULTS AND DISCUSSIONS

4.1 Functional properties of the flours

Functional properties are the fundamental properties that reflect the complex interaction between the composition, structure, molecular conformation, and physiochemical properties of food components together with the nature of the environment in which these are associated and

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measured (Ngozi *et al.*, 2021). They are as presented in Table 1. Bulk density (BD) is a measure of heaviness of a flour sample (Bolaji *et al.*, 2021). The BD of the yam flours (0.70-0.84 g/cm^3) align with the work of Chandra&Samsher, (2013), who obtained range of 0.72-0.91 g/cm^3 probably because their work also, was from single flours -wheat, rice, millet and potato flours as is 100% yams flours in this study. Higher bulk density is desirable for greater ease of dispersibility and reduction of paste thickness; while, low bulk density of flour is a good physical attribute when determining transportation and storability (Awolu *et al.*, 2017). Thus, the lesser the bulk density, the more packaging space is required. The bulk density of the AR was the lowest (0.70 g/mL). Implying that the AR would require more packaging space than the other yam flours. Dispersibility is the ability of flour to get wet without the formation of lumps in water. The dispersibility was significantly ($p<0.05$) different amongst the samples. The result obtained is lower than the dispersibilities of the flour blends (64.67 to70.0 %) reported by Adeola, *et al.*, (2017) for sorghum, pigeon pea and Soybean flour blends. The lower values have important significance; this infers that, all the flours will comparatively reconstitute effortlessly to fine consistent dough/batter during mixing (Adeola, *et al.*, 2017). Water absorption capacity (WAC) describes flour-water association capability under limited water quantity. Presence of carbohydrates in higher concentration encouraged hydrogen bonding between polar side chains of flour constituents and water and leads to rise in WAC

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(Wani & Qadir, 2023). From results, the lowest value (0.87ml/g) was observed in WF and differ significantly ($p>0.05$) from all the flours which were higher. The WAC of the yam flours ranged from 1.93-2.53 ml/g ^ compared favorably with 2.32-2.76 ml/g reported for *yam* flours by Ayo *et al.*, (2017). It has been suggested that flours with such WAC as seen in this study

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will be very useful in bakery products such as Cookies, Biscuits etc., as this could prevent

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staling by reducing moisture loss (Bolaji *et al*., 2021). Thus, ability of these flours to absorb and retain water indicates they would performance better in texture and baked products which aligns with Olaitan *et al*., (2017). Oil absorption capacity (OAC), measures capacity of a food material to absorb oil. It is the flavor retaining capacity of flour and improves mouth feel, which is very important in food formulations (Ohizua, *et al*.,2017). Hence, the OAC of the Yam flours which ranged 1.03-2.03 mL/g and agrees with the value (1.18 mL/g) of Olumurewa *et al*., (2019). The mechanism of fat absorption is attributed mainly to the physical entrapment of oil and the binding of fat to a polar chain of protein. The protein in foods stimulate fat absorption, hence OAC of foods increase with increased protein content (Chandra *et al*., 2015). There was

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significant (p<0.05) difference amongst samples. The highest AR and lowest GB. This implies; AR had highest protein content and would retain flavor more. GB was lowest in protein. this is in consonance with the work of Wani & Qadir, (2023) who reported that Polishing of rice which reduce concentration of proteins led to significant (P < 0.05) reduction in OAC of rice flours. Thus, AR will potentially be useful in structural interaction in food especially in flavour retention, improvement of palatability and extension of shelf life of baked products where fat

incomplete

absorption is desired. Swelling index (SI) of flours depends on size of particles, type of variety and types of processing methods under gone. There were significant (P<0.05) differences in the SI of all Samples. The Hk had the highest (2.07ml/g) which could be attributed to its of variety yam (Chandra & Samsher, 2013). The lowest SI observed in WF (Wheat flour), implies that, the processing it underwent had significant effect on its particle size. Swelling capacity (SC) is a function of the process conditions, nature of the material and type of treatment. The SC is used in the determination of the amount of water that food samples can absorb and the degree of swelling within a given time. High SC has been reported as part of the criteria for a good quality product (Adebayo-Oyetoro, *et al*., 2013).

This sentence is not clear because the OAC and the flavour retaining capacity are not the same

Table 1 Functional properties of the flours

SAMPLES	Bulk Density (g/cm^3)	Dispersibility (g/mL)	Water Absorption Capacity (mL/g)	Oil Absorption Capacity (mL/g)	Swelling Index (mL/g)	Swelling Capacity (%)
WF (Wheat flour-Control)	$0.79^{b}\pm0.00$	$23.17^{a}\pm0.29$	$0.87^{a}\pm0.06$	$1.07^{b}\pm0.06$	$0.92^{a}\pm0.07$	$146.30^{a}\pm0.58$
OG (Ogoja yam flour)	$0.84^{d}\pm0.00$	$37.33^{d}\pm0.58$	$2.47^{c}\pm0.06$	$1.03^{b}\pm0.06$	$1.25^{b}\pm0.06$	$154.94^{b}\pm0.05$
FT (Faketsa yam flour)	$0.81^{c}\pm0.00$	$27.33^{b}\pm0.58$	$2.03^{b}\pm0.06$	$1.07^{b}\pm0.06$	$1.80^{e}\pm0.04$	$244.86^{e}\pm0.50$
HK (Hembakwase yam flour)	$0.79^{b}\pm0.01$	$33.50^{c}\pm0.58$	$2.03^{b}\pm0.06$	$1.03^{b}\pm0.06$	$2.07^{f}\pm0.04$	$265.82^{f}\pm0.13$
AR (Amura yam flour)	$0.70^{a}\pm0.01$	$39.33^{e}\pm0.58$	$1.93^{b}\pm0.06$	$2.03^{c}\pm0.06$	$1.61^{d}\pm0.05$	$232.18^{d}\pm0.14$
GB (Gwebe yam flour)	$0.80^{c}\pm0.00$	$27.50^{b}\pm0.50$	$2.53^{c}\pm0.06$	$0.93^{a}\pm0.06$	$1.44^{c}\pm0.07$	$218.08^{c}\pm0.00$

Values are mean ± SD of triplicate determination. Samples with different superscripts within the same column were significantly ($p<0.05$) different.

Indigenous names should be italicized or written in quotes

I suggest the highest values be attached the superscripts ‘a’ not the lowest. This is for easy identification of mean differences

4.2 Pasting properties of the flours:

Pasting property is an index for forecasting a food’s capacity to form a paste on exposure to heat applications. Pasting occurs after or simultaneously with gelatinization. Food starch is altered into solid state advantageous in several food systems through gelatinization which is an endothermic process, resulting in derangement of molecular order inside the starch granules (Iwe, *et al*., 2017). Pasting properties of the flours are as presented in Table 2. There was significant ($p<0.05$) difference in all the parameters of the samples examined. The peak viscosity (PV) is the maximum viscosity attainable during the heating cycle. It indicates the water-binding capability of starch and capacity of the starch to swell before it physically breaks down (Onyeneke, 2019). Products that have high PV do not swell easily, requires a lot of energy to initiate swelling, gelatinization and have high pasting temperatures. PV also shows the viscous load likely to be encountered during mixing (Eze *et al*., 2022). In this study, the PV ranged 1285.00-4586.33RVU, the lowest in AR and highest in OG. Indicating that OG has high amylose and starch content and will form a thicker viscous gel on cooking, more than the other flours. Hence, may be more suitable for products which require high gel strength. Trough viscosity is considered as a measure of the breakdown of hot starch paste during cooling which is also referred to as shear thinning, holding strength, or hot paste viscosity, it is the minimum viscosity value in the constant temperature phase of the RVA profile usually occurs around the commencement of sample cooling (Oluwamukomi&Jolayemi, 2012). Higher values of trough indicate a paste with less stability to breakdown and prone to disintegration. Lower values suggest suitability for formation of stable paste (Adeloye *et al*., 2020). High paste stability is a requirement for industrial users of starch because drastic changes in paste during and after processing could result to undesirable textural changes (Eze *et al*., 2022). The hot paste viscosity (Trough) of the yam flours ranged 1102.00-4035.00RVU. There were significant ($p<0.05$) difference in all the samples. OG had highest holding strength 4035.00RVU than the

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Sentence is too long consider breaking it down other flours, while AR recorded the lowest 1102.00 RVU. By implication; OG has less stability to breakdown and prone to disintegration. While AR would be suitability for formation of stable paste and could be targeted for industrial uses. Breakdown viscosity is a measure of vulnerability of cooked starch granules to degeneration and is shown to affect the stability of flour products. It illustrates the capability of flour to tolerate controlled heating and use of shear in the course of food processing (Adeloye *et al*., 2020). The ability of a mixture to withstand heating and shear stress that is usually encountered during processing is an important factor for many processes especially those requiring stable paste and low retrogradation/syneresis. The lower the value the more stable the starch gel. Higher values of breakdown are associated with higher peak viscosities (Oluwamukomi&Jolayemi,2012). Starches with low paste stability and high breakdown have very weak cross-linking within granules indicating less stability to paste breakdown (Lin *et al*., 2023). There was significant ($p<0.05$) difference in breakdown viscosities of all samples ranging from 674.00-57.07 RVU. GB had the highest value while HK had lowest, followed by AR(184.00 RVU). HK value was close to the value obtained by Oke&Bolarinwa, (2012) for 24h fermented cocoyam flour (58.83 RVU). This suggest that HK and AR have better chances of withstanding heating and shear stress during processing, hence would fit products that need cohesiveness like biscuits, cookies or products that require good mouldability dough like pounded yam flour (Eze *et al*., 2022) of which, these flours are targeted for. Final viscosity also, called Cold paste viscosity, (CPV) is the viscosity at end of the test, it is the most commonly used parameter to define the quality of a particular starch-based sample, as it shows the capacity of the material to form a viscous paste or gel after cooking and cooling, also; the effect of texture modifiers on the physicochemical resistance of the paste to shear force during stirring (Adeloye *et al*., 2020). During the final cycle of cooling from 95℃ to 50℃, the viscosity increased to a final viscosity owing to the alignment of the chains of amylose resulting in formation of a gel structure. The values, 1878.33-6428.00RVU, obtained

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*the sentence needs to broken to make it more meaningful for final viscosity of the flours indicate better final viscosity quality. It is important in predicting and defining the final textural quality of the product in terms of springiness (drawability). High CPV implies firm gel formation after cooking and cooling to 5^0C rather than a viscous paste (Oluwamukomi&Jolayemi, 2012). Flours with lower final viscosity could be suitable for nutritious and less viscous complementary foods (Adeloye *et al*., 2020). The "setback" value is related to the amylose content, retrogradation and reordering of starch molecules. High set back is associated with syneresis, or weeping, during freeze/thaw cycles (Unaeze, *et al*., 2022). The setback refers to viscosity after cooling to 50°C of cooked paste. It is a stage where retrogradation or re-ordering of starch molecules occurs. It is a tendency to become firmer with increasing resistance to enzymic attack (Oluwamukomi&Jolayemi, 2012). Flours with higher setback values are susceptible to retrogradation, syneresis and lower digestibility. Flours with low setback may have low values of amylose which have high molecular weight. This suggests highly digestible food product could be made from flours having low setback value. Data from this study showed HK and AR with lower setback values 688.00 and 777.00RVU respectively^ hence low rate of retrogradation and syneresis and higher digestibility. The setback revealed the gelling ability or retrogradation tendency of the amylose. Thus; the highest value (2393.33 RVU) observed in OG suggested that the highest amylose retrogradation occurred in OG (Adeloye *et al*., 2020). The peak time is a measure of the cooking time taken to cook to reach the maximum starch gelatinization and peak viscosity. Low peak time is indicative of ability to cook fast (Adeloye *et al*., 2020). AR had lowest cooking time (5.40Min), while OG had highest cooking time (7.20min). This could be due to differences of the yam varieties. The time to attain peak viscosity of the flours (5.4-7.20mins) were higher than time reported by Oluwamukomi & Jolayemi, (2012) for gari which ranged between 3.93-4.07 min. Probably, due to the toasting processing resulting to partially gelatinization that gari undergoes in the course of its production. Pasting temperature (PT) is a

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measure of the minimum temperature necessary to cook a given food sample (Adeloye *et al*., 2020). It is the temperature at the onset of gelatinization at which irreversible swelling of the starch granule occurs, resulting to a viscous paste formulation in aqueous solution (Wahab *et al*., 2016). It can have inferences for the stability of other components in a formula and also shows energy costs. The PT ranged 81.50 - 88.85°C; AR lowest and OG highest. This result is consistent with Oluseye *et al*., (2018) who got PT of 81.81 and 84.80 °C for 100% D. cayenensis and D. alata respectively. Confirming that, these yam flours would form thick paste/dough for baking to obtain good quality bake products. The high pasting temperature of OG indicated the presence of starch that is highly resistance to swelling and rupturing (Wahab, *et al*., 2016). Generally, the pasting temperatures of the flours were lower than boiling temperature; thus all flours could form a paste in hot water below boiling point.

italics

How about baked

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Table 2: Pasting properties of the flours

SAMPLE	Peak Viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Set back (RVU)	Peak Time(Min)	Pasting Temp(^oC)
WF	2170.33^b±1.53	1124.00^b±1.00	1046.00^f±1.00	2109.00^b±1.00	985.00^c±1.00	6.93^d±0.01	88.80^e±0.10
OG	4586.33^f±1.53	4035.00^f±2.00	551.33^d±0.58	6428.00^f±1.00	2393.33^f±3.52	7.20^e±0.20	88.85^e±0.02
FT	3837.00^d±1.00	3470.00^e±1.00	367.00^c±2.00	4693.00^d±1.00	1223.00^d±1.00	6.10^{bc}±0.10	84.13^c±0.15
HK	2915.00^c±1.00	2858.00^c±1.00	57.07^a±0.21	3546.00^c±1.00	688.00^a±1.00	5.93^{ab}±0.10	83.90^b±0.20
AR	1285.00^a±1.00	1102.00^a±1.00	184.00^b±1.00	1878.33^a±0.58	777.00^b±1.00	5.40^a±0.10	81.50^a±0.10
GB	3933.00^e±2.00	3259.00^d±2.00	674.00^e±1.00	5154.00^e±1.00	1895.33^e±1.53	6.20^c±0.10	87.25^d±0.01

Values are mean ± SD of triplicate determination. Samples with different superscripts within the same column were significantly ($p<0.05$) different. ***** RVU - (Rapid Viscometric Unit)

I suggest the highest values be attached the superscripts 'a' not the lowest. This is for easy identification of mean differences

4.3 Proximate Composition and Energy Value of the flours

Proximate composition of the flours are as presented in Table 3.

The proximate composition of foods is used to determine the nutritive value and acceptability of the food product. Moisture content (MC) of flour is very important for it shelf life, the lower flour moisture, the better it storage stability. The MC of the flours ranged from 7.61- 9.70%. The least been GB and highest HK. There was significance (P<0.05) difference amongst all the samples. The MC result, indicated all flours had MC below 10% which showed good keeping quality of the flours. This align with findings of Ojo *et al.* (2017) who also reported low moisture of flours as 7.68–10.55%. The MC of all the flours was below the recommended safe level (12–13%) for storage of flour. Implying that the flours might store for a long period without microbial contamination, if properly packaged in an airtight material (Adebowale *et al*., 2017). Ash refers to the inorganic residue in any food material and it directly signifies the total amount of minerals present within the food. Less was observed in FT and higher in AR. The ash content of yam flours (2.50-3.80%) fall within the range as reviewed by Obidiegwu *et al*., (2020) which ranged from 0.1%-8.8% and is comparable to the values gotten in the work of Ojo *et al*., (2017) where the ash content of bitter and yam ^water yam flours were 2.46% and 3.33%. The relatively high protein contents observed in the yam flours was in consonance with the work of Franklin W. Martin and A. E. Thompson (1971) who reported protein values of D. alata as average of 8.19% protein, with a range of 6.72 to 9.75%, and white Yams (Dioscorea spp.) as 6.3-13.4% crude protein. He explained that; protein content tended to be highest in upper or inner (oldest) portions of the yam tubers. The yams in this research were old yam gotten in the month of August 2022 when yams are out of stock. Thus; could be the reason for their relatively high protein (7.77-9.27%) content. This aligns with Obidiegwu *et al*., (2020) who reported a study on the effect of storage on nutritional content of yam which showed an increase in protein content, total sugar and reducing sugar as 13.0%–14.6%, 6.5%–

Unfortunately, you didn't investigate sugars, why are they cited here?

9.8% and 1.7%–2.3%, respectively. Ranges of the water yam (Gwebe) in this work were within similar to that of water yam reported by Ojo *et al*., (2017) as 7.05+0.15 (protein), 1.95+0.10(fat), 10.47+0.10(moisture), 3.33+0.00(ash), 3.33+0.00(fiber) and 73.76+0.71(carbohydrate). Also, the protein and starch content of the water yam (Gwebe) aligned with range reported by Djeri,*et al*., (2015) who had a crude protein content of 7.4%, starch content of 75–84%, respectively. Fat had been reported in yam. However, in very small fraction and have a great impact on the functionality of starch. A wide range of concentrations of fat between 0.03% and 10.2% have been reported by Obidiegwu *et al*., (2020). The Yam flours had very low fat values 1.19-1.34% indicating the flours are not good source of fat. The carbohydrate content generally was high across all the flours and this account for high energy calories observed in the flours.

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Table 3: Proximate Composition and Energy Value of flours

Samples	Moisture (%)	Ash (%)	Fiber (%)	Protein (%)	Fat (%)	Cho (%)	Energy (Kcal)
WF	9.40^{cd}±0.16	1.57^{a}±0.14	0.10^{a}±0.01	8.41^{b}±0.40	1.51^{a}±0.42	79.01^{e}±0.29	343.52^{d}±4.39
OG	9.69^{d}±0.05	3.22^{d}±0.13	2.81^{c}±0.05	9.26^{c}±0.05	1.32^{a}±0.17	75.09^{a}±0.31	330.51^{b}±0.81
FT	9.20^{c}±0.04	2.50^{b}±0.12	4.59^{e}±0.17	8.32^{b}±0.26	1.24^{a}±0.10	76.15^{c}±0.26	330.00^{b}±1.23
HK	9.70^{d}±0.23	2.81^{c}±0.05	4.82^{f}±0.12	7.82^{a}±0.09	1.34^{a}±0.02	75.51^{b}±0.29	326.50^{a}±1.16
AR	8.27^{b}±0.03	3.80^{e}±0.07	2.91^{c}±0.02	9.27^{c}±0.05	1.34^{a}±0.02	76.41^{d}±0.06	335.68^{c}±0.21
GB	7.61^{a}±0.36	3.76^{e}±0.04	2.12^{b}±0.01	7.77^{a}±0.01	1.19^{a}±0.12	79.55^{f}±0.42	340.10^{d}±2.44

Values are mean ± SD of triplicate determination. Samples with different superscripts within the same column were significantly ($p<0.05$) different.

I suggest the highest values be attached the superscripts 'a' not the lowest. This is for easy identification of mean differences

4.4 Vitamin content of the flours (mg/100g).

Vitamins A,C,E,D,K and B content of the flours are as presented in Table 4.

Missing word 'from'

Vitamin A; ranged ^ 66.4-807.55 mg/100g which is much higher than range 17.70-23.00

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mg/100g reported by Ojo et al., (2017). Probably as a result of the processing method engaged

Revise this sentence

to produce the yam flours. lowest in FT and highest in AR. There was significant ($p<0.05$) difference amongst the samples. Vitamin A is fat-soluble and plays central role in various

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aspects of health; including Vision Health, antioxidant activity, immune boosting, maintenance of skin cells, reducing inflammation, growth and development (Khadim & Al-Fartusie, 2021).

Revise sentence

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Vitamin C ranged 21.06-28.73 mg/100g showed values close to Djeri,*et al.*, (2015) where Vitamin C content ranged from 13.0-24.7mg/100g. This result is also in consonance with f

Revise sentence

Adebowale *et al*., (2018)' report; where vitamin C, ranged 20.87-30.91mg/100g. Vitamin C is water-soluble, an antioxidant, important for skin, bones, and connective tissue, stimulate the production of white blood cells, supports wound healing, helps the body absorb iron (Seth *et al*., 2024), lower risk of developing cataracts and age-related macular degeneration, lessen the severity and extent of respiratory infections and also helpful for asthmatic persons by decreasing inflammation in the airways (Gombart *et al*., 2020). Vitamin E, which is a fat-soluble, plays an imperative role in the strengthening of immune function, maintenance of healthy skin/eyes, strong antioxidant that aids in the absorption of iron in the body

'ly'

(Khadim&Al-Fartusie, 2021). Its range 0.08-0.25mg/100g compares favourable with 0.33-0.37mg/100g reported by Ojo et al., (2017). Vitamin D was detected in just trace amount in all

Vitamin K ranged highest (values) in AR and lowest.......

the samples. Vitamin K, ranged 0.12-0.74mg/100g. Highest in AR and lowest in GB indicating

It is?

that the AR would contributes more the benefits of Vitamin K. Its fat-soluble, best known for its role in helping blood to clot coagulate properly, maintain bone health, keep blood vessels functioning properly (Seth *et al*.,2024). Vitamin B_1 (thiamine) ranged 0.73-0.83mg/100g obtained in our work falls within the range 0.18–1.05mg/100g gotten by Adebowale *et al*.,

Revise the sentence

(2018). The lower values obtained in our study may be as a result of genetic, interspecies variations and environmental factors. Thiamine is essential for glucose metabolism, proper functioning of the nerves, digestion, muscles and hearts (Okoye et al., 2024).

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Table 4. Vitamin content of the five Yams variety and wheat (control) flours. (mg/100g)

SAMPLES	VIT A	VIT C	VIT E	VIT D	VIT K	VIT B_1
WF	123.13^{b}±0.84	26.68^{d}±0.06	0.18^{c}±0.01	0.00^{b}±0.00	0.14^{b}±0.01	0.77^{b}±0.01
OG	349.25^{e}±0.95	26.56^{c}±0.06	0.12^{b}±0.02	0.00^{d}±0.00	0.16^{c}±0.01	0.75 ^{b}±0.01
FT	066.41^{a}±0.82	27.02^{e}±0.06	0.11^{b}0.01	0.00^{e}±0.00	0.22^{d}±0.01	0.74 ^{a}±0.01
HK	158.14^{d}±0.82	21.06^{a}±0.06	0.25^{d}±0.02	0.00^{c}±0.00	0.15^{bc}±0.01	0.73 ^{a}±0.01
AR	807.55^{f}±1.22	28.73^{f}±0.01	1.24^{e}±0.01	0.01^{f}±0.01	0.74^{e}±0.02	0.83^{c}±0.00
GB	131.41^{c}±0.81	23.40^{b}±0.06	0.08^{a}±0.02	0.00^{a}±0.00	0.12^{a}±0.01	0.76 ^{b}±0.01

Values are mean ± SD of triplicate determination. Samples with different superscripts within the same column were significantly ($p<0.05$) different.

I suggest the highest values be attached the superscripts ‘a’ not the lowest. This is for easy identification of mean differences

4.5 Mineral content of the flours (mg/100g).

Minerals are inorganic elements essential for the normal functioning of the body and are as presented in table 5. They are required in smaller quantities and are not destroyed by heating. Sodium(Na) is the principal extracellular cation and is used for acid-base balance and osmo-regulation, stimulates cell proliferation, protein synthesis, increase cell mass, maintaining blood pressure and fluid balance (Iombor *et al.*, 2019). The Na ranged 47.42-59.51mg/100g. GB lowest (add value) and FT highest (add value). The WHO recommends Na intake per day as 500 and 400 mg for adult and children respectively. Hence, flours in this work are not sufficient sources of Na, but could be perceived as a positive factor in low salt diets (Godfrey *et al.*,2023). Potassium consumption is essential in comparatively huge quantity in the body because it functions as a vital electrolyte in the nervous system, regulates acid-base balance, triggers nerve and muscle function, maintenance osmotic pressure of the body fluids (Ufot, *et al.*, 2018). The potassium content of HK(69.01mg/100g), FT(74.02mg/100g) and OG(85.02mg/100g) falls within the range (add the value here and remove it after citation)

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reported by Okoye *et al.*, (2024) as (78.34mg/100g). while potassium content of GB(98.02mg/100g) and AR(123.51mg/100g) were higher than their values. The high values, makes them better potassium source than other tubers and possibly suitable for hypertensive individuals (Obidiegwu *et al.*, 2020). Calcium content ranged 25.28-33.01mg/100g. It plays key role in muscle function, formation and strengthening of bones, teeth, conducting nerve impulses, blood clotting and maintaining normal heartbeat (Araujo *et al.*, 2016). Ages 18-50years require 1,000mg of calcium/day while less than 18years need more concentration of 1,300mg calcium for developing bones and teeth (Omohimi *et al.*, 2018). Magnesium controls protein synthesis, blood glucose, blood pressure regulation, muscles and nerve functions. The RDA of Mg for adult is 350 and 170 mg/day for children (Godfrey *et al.*, 2023). In this work; range is 39.18-58.02 mg/100g. Phosphorus helps to strengthen bones and teeth, particularly in children and breastfeeding mothers. The RDA for both children and adults is 800mg/day

(Godfrey *et al*., 2023). Our data showed range of 2.95-5.43mg/100g. The low Phosphorus concentration of the yam flours indicates that their consumption alone will not supply the recommended RDA of 800 mg/day for both adults and children, except when consumed with other Phosphorus rich foods Omohimi *et al*., (2018). Zinc functions to; improves immune system, insulin function, cell growth, wound healing, cell development and replication, Okoye *et al*., (2024). RDA of Zn is 8mg/day for females and 11mg/day for males. (Omohimi *et al.*, 2018). Its range 0.80-1.25mg/100g is below the RDA. However, it falls within range of 1.78 mg/100g reported by Okoye *et al*., (2024). Manganese aids in formation of connective tissues, bones, blood clotting factors, sex hormones, fat and carbohydrate metabolism, calcium absorption and regulating blood sugar level (Okoye *et al*., 2024). RDAs for females and males are 1.2 and 2.3 mg/day (Omohimi *et al.*, 2018) which is higher than the range in this work (0.04-0.12mg/100g). Thus, need to be combined with other foodstuffs in the diets to make up for inadequacy. Ingestion of foods made from our yam flours with inclusion of dark green leafy vegetables could make up for inadequacies (Omohimi *et al*., 2018). Overall, our data revealed that; AR generally had higher mineral content above the other yam flours.

Table 5. Minerals Content of the flours (mg/100g)

SAMPLE	Na	K	Ca	Mg	Mn	P	Zn
WF	$59.73^{f}\pm0.06$	$92.02^{d}\pm0.02$	$32.72^{e}\pm0.02$	$53.22^{d}\pm0.02$	$0.06^{b}\pm0.00$	$5.05^{e}\pm0.00$	$0.79^{a}\pm0.00$
OG	$49.52^{b}\pm0.02$	$85.02^{c}\pm0.02$	$25.28^{a}\pm0.02$	$47.64^{c}\pm0.03$	$0.08^{c}\pm0.00$	$5.43^{f}\pm0.01$	$0.80^{b}\pm0.01$
FT	$59.51^{e}\pm0.01$	$74.02^{b}\pm0.02$	$29.58^{d}\pm0.03$	$55.84^{e}\pm0.01$	$0.06^{b}\pm0.00$	$4.35^{cd}\pm0.00$	$0.85^{c}\pm0.00$
HK	$54.21^{d}\pm0.01$	$69.01^{a}\pm0.01$	$25.81^{b}\pm0.02$	$41.27^{b}\pm0.02$	$0.04^{a}\pm0.01$	$4.03^{b}\pm0.01$	$1.02^{d}\pm0.02$
AR	$54.02^{c}\pm0.02$	$123.51^{f}\pm0.02$	$33.01^{f}\pm0.01$	$58.02^{f}\pm0.02$	$0.12^{d}\pm0.01$	$4.55^{d}\pm0.43$	$1.25^{f}\pm0.01$
GB	$47.42^{a}\pm0.02$	$98.02^{e}\pm0.02$	$28.59^{c}\pm0.02$	$39.18^{a}\pm0.02$	$0.04^{a}\pm0.00$	$2.95^{a}\pm0.01$	$1.04^{e}\pm0.01$

Values are mean ± SD of triplicate determination. Samples with different superscripts within the same column were significantly ($p<0.05$) different.

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5. CONCLUSION

The yam flours exhibited good quality functional and pasting properties and demonstrated relatively good quality in terms of nutritional composition. They also competed favorably with the standard wheat flour in all parameters investigated, so are recommended to be used partially or wholly to replace wheat in confectioneries production.

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