

**CHEMICAL, TECHNO-FUNCTIONAL, AND ANTIOXIDANT PROPERTIES OF TIGERNUT (*CYPERUS ESCULENTUS* L.) RESIDUE FLOURS****Oladele, A. K.\*, Liman, A. A., Abass, M. F. and Ekawu, B.**

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\*Corresponding author: [kanmiladele@gmail.com](mailto:kanmiladele@gmail.com). Phone number: +2348075165370**ABSTRACT**

Tigernut processing generates nutritionally-rich residue, mostly discarded as waste. This research reports for the first time the amino acid profile, phenolic profile, and pasting properties of tigernut residues. Yellow and brown tigernut residues were analysed for amino acid and phenolic profile, antioxidant, techno-functional and pasting properties. The total essential amino acids were 49 and 56% for yellow and brown tigernut residue flours, respectively. The flavonoid content and ferric reducing antioxidant property were 0.91 and 0.32 mg GAE/ g, and 3.43 and 1.41 AAE/ g for yellow and brown residue, respectively. Caffeic acid (29 – 56 mg/ 100 g), ferulic acid (39 mg/ 100 g), vanillic acid (38 mg/ 100 g), Quercetin (48 mg/ 100 g), and phenyl acetic acid (3 – 68 mg/ 100 g) occur in abundance in the residue flours. The oil absorption capacity (3.40 ml/ g), L\* value (63.78), and b\* value (15.61) were higher in yellow than in brown residue. Brown tigernut residue flour cooked faster (5.77 min) than yellow tigernut residue flour (6.97 min). Some essential amino acids detected were lysine, leucine, and methionine. The reports obtained in this work showed that tigernut residues have the potential to be incorporated in food due to their richness in essential amino acids, phenolic compounds, and antioxidant activity.

**Keywords:** Tigernut; *Cyperus esculentus*, residue flour; Techno-functional properties; pasting properties**INTRODUCTION**

There has been a shift in the demand from nutritional foods to functional foods by consumers due to the nutraceutical properties such as antioxidant and anticancer properties. Functional foods offer some health benefits apart from the required nutrients (Oladiran and Emmambux, 2017). To this end, many foods have been fortified with food components such as dietary fibre and polyphenols that could perform nutraceutical functions (López-marcos *et al.*, 2015).

Dietary fibre contributes to the well-being of the body by increasing faecal weight and volume, prevents constipation and colon cancer, stimulate colonic fermentation, and improve satiety (Elleuch *et al.*, 2011). Polyphenols, which are secondary plant metabolites, on the other hand, regulate postprandial glucose and prevent diabetes and can chelate disease-causing free radicals. This can prevent cardiovascular diseases such as cancer and other related diseases (Adarkwah-Yiadom and Duodu, 2017).

In the formulation of functional foods, efforts are geared towards the incorporation of components or whole waste products from plants (Castrica *et al.*, 2019). Many plant materials and their processing wastes; including sorghum bran, wheat bran, orange pulp, orange fibre, orange peel, grape pomace, tigernut, etc., are rich in dietary fibre and polyphenols (Beta *et al.*, 2005; Oladiran and Emmambux, 2018; Roselló-soto *et al.*, 2018) and have been incorporated in foods. Most of the developed food products have improved nutrition and nutraceutical properties (Roselló-soto *et al.*, 2018).

Tigernut (*Cyperus esculentus* L.) also known as earth almond, chufa, yellow nutsedge, (*ayaya*, *ofio*, and *Imumu* in Nigeria) is a good source of starch ( $\leq 35\%$ ) and oil ( $\leq 30\%$ ) (Builders *et al.*, 2014). Although low in protein content, the essential amino acids such as methionine, threonine, and lysine are present in tigernut (Yu *et al.*, 2022). Tigernut contains high content of dietary fibre and polyphenols (Oladele *et al.*, 2017; Yu *et al.*, 2022). Pharmacological tests showed that alcoholic extracts of tigernut have antidiabetic effect (Badejo *et al.*, 2020), anticancer (Achoribo and Ong, 2017), anticonvulsant and antioxidant properties (Ayyanna *et al.*, 2020). The milky drink obtained from tigernut also suppressed hepato-renal oxidative stress and inflammation (Eskander *et al.*, 2020).

Tigernut is usually consumed raw, dried, roasted or sometimes processed into milk (*Horchata de chufa* (Spain) or *Kunnu ayaya* (Nigeria)) (Builders *et al.*, 2014; Ejoh *et al.*, 2021) or starch (Agboola *et al.*, 2018; Liu *et al.*, 2021). The processing include soaking of tigernut, milling, and sieving. After sieving, about 60% weight of the raw material is generated as waste which is either fed to animals or discarded thereby constituting environmental pollution.

Tigernut and its by-products are remarkable sources of dietary fiber and some bioactive compounds such as polyphenols (Roselló-soto *et al.*, 2018). Moreover, tigernut oil is rich in monounsaturated fatty acids, and sterols (tocopherols and phytosterols). These properties can be used to modify the technological and functional properties of foods (Sánchez-zapata *et al.*, 2013), and production of dietary fiber as it is rich in dietary fiber (Sanchez-Zapata *et al.* 2009) Most of the research on tigernut have focussed on the processing while there

are scarce reports on characterisation of the by-products obtained from tigernut processing. Therefore, the objective of this research was to determine the chemical, techno-functional and antioxidant properties of tigernut residue towards incorporating it in product development.

## MATERIALS AND METHODS

### Materials

Tigernuts (*Cyperus esculentus* var. *sativus*) (yellow and brown variety) were bought from Monday market in New Bussa, Niger State, North-Central Nigeria. Methanol and acetonitrile (LICHROSOLV®) were HPLC grade while glacial acetic acid, and phenolic standards (gallic acid, catechin, caffeic acid, syringic acid, and chlorogenic acid) were of analytical grade and were used without further purification.

### Sample preparation

Tigernuts were picked manually to become free of stones, and other unwanted materials, washed and dried in the oven ( ) at 60 °C for 24 h. The seeds were soaked (1:10, w/v) in sodium metabisulphite solution (3.2 g/ L) for 48 h with a change of the solution after 24 h. The sample was milled with the sodium metabisulphite solution (3.2 g/ L) and sieved with a muslin cloth to obtain starch milk (Builders *et al.*, 2014). The residue was air-dried at ambient temperature (28 ± 2 °C) for 24 h before oven-drying at 50 °C for 24 h. The residue was milled in a local attrition mill and sieved with a mesh (500 µm). The samples were stored in a freezer at -20 °C until analysed. Residue flours from yellow and brown tigernut were tagged YTRF and BTRF, respectively.

### Methodology

#### Amino acids analysis

The AOAC (2005) methods with some modifications was used to determine the amino acid content of the flours. Four grams (4 g) of tigernut residue flour was defatted with chloroform: methanol mixture (2:1, v/v) from which 1 g was hydrolyzed and evaporated in a rotary evaporator before 60 µl of the hydrolysate was injected into an amino acid analyser (PTH Amino acid analyser, Applied Biosystems, Germany). The concentration (based on peak area) of the individual amino acid was calculated by an integrator attached to the Analyzer.

#### Extraction of samples

The phenolic compounds in the flours were extracted following Apea-Bah *et al.* (2017) method. Ten milliliter (10 mL) of acidified methanol (Hydrochloric acid 1%) was added to 3 g of the sample and stirred for 2 h with a magnetic stirrer on a hot plate. After centrifugation (3500 rpm) for 10 min and decantation, the residue was extracted again with another 10 ml

acidified methanol for 30 min, centrifuged and decanted. The above process was repeated before the extracts were pooled and stored for analyses.

#### Flavonoid content

The Apea-Bah *et al.* (2014) method was used to determine the flavonoids in the flours. Sample extract (1 mL) or standard solution (gallic acid) of varying concentrations and distilled water (4 ml) were added to a 10 ml flask. At zero-minute, 0.3 mL 10 % AlCl<sub>3</sub> was added while 2 ml 1 M NaOH was added after six minutes. The solution was diluted to the mark with distilled water and mixed thoroughly. The absorbance at 510 nm was read in a spectrophotometer. The results were expressed in gallic acid equivalent (GAE)/gram of sample

#### Total phenolic content

The phenolic content of the sample flours was determined following the spectrophotometric method described by Apea-Bah *et al.* (2014). Seven millilitres (7 mL) of distilled water and 0.5 ml Folin – Ciocalteu reagent were added to 1 ml sample extract. This was followed by the addition of 1.5 mL 20 % (w/v) sodium carbonate solution and mixing. Incubation for 7–8 min followed before the test tube was filled to 10 mL mark with distilled water. The absorbance of the mixture incubated for 2 h at 30 °C was read in a spectrophotometer at 765 nm. The results were expressed as gallic acid equivalent (GAE)/ g sample.

#### Ferric reducing antioxidant power

The ferric reducing antioxidant power (FRAP) assay was carried out as described by MacDonald-Wicks *et al.* (2006). The working FRAP solution included 2,4,6-Tripyridyl-S-triazine (TPTZ, 0.01 M dissolved in 0.04 M HCl), FeCl<sub>3</sub>.6H<sub>2</sub>O (0.02 M in water), and acetate buffer (0.3 M, pH 3.6) at the ratio of 1:1:10. Three millilitres (3 ml) of a freshly prepared FRAP solution was reacted with the extract (1.0 ml). The absorbance at 593 nm was read after 30 min.

#### Phenolic profile

The phenolic composition of the residue flours was determined using a normal phase High performance liquid chromatography (Model N2000, SearchTech Instrument, UK). Sample extract was filtered with 0.85 µm micron filter into a sample bottle (5 ml) from where 40 µL was injected into the machine. The mobile phase (acetonitrile, water, and acetic acid; 19:80:1) run through a column temperature of 40 °C at 272 nm for 25 min. Reference standards and sample extracts were run under the same condition. The retention time of the phenolic compounds in the sample extract was compared to that of the standards and those in the literature. Quantification was by integration of the peak areas of the identified compounds.

## Determination of techno-functional properties

### Water and oil absorption capacities

Adebowale and Lawal (2004) methods were adopted for the water and oil absorption capacities. Ten milliliters (10 mL) of water or vegetable oil was added to 1 g of sample in a centrifuge tube and mixed. This was allowed to stand at room temperature (30 ± 2 °C) for 1 h before centrifugation (2000 x g) for 30 min. The unabsorbed oil or water decanted and measured. The results were expressed as mL of water or oil absorbed per gram of flour.

## Foam capacity and stability

The method described by Adebowale and Lawal (2004) was used for the determination of foam capacity (FC) and foam stability (FS). In a 100 mL measuring cylinder, 2 g of the sample and 50 ml distilled water were mixed and thoroughly shaken until foamed. The volume of the foam was recorded after 30 s to calculate foam capacity expressed as a percentage increase in volume. Foam stability was obtained as the percentage decrease in the foam volume after 1 h.

$$\text{Foam capacity} = \frac{\text{Volume after whipping} - \text{volume before whipping}}{\text{Volume before whipping}} \times 100 \quad \dots \text{Eqn 1}$$

$$\text{Foam stability} = \frac{\text{Foam volume after time } t \times 100}{\text{Initial foam volume}} \quad \dots \text{Eqn 2}$$

### Loose and bulk density

Flour sample (20 g) was weighed into a 200 ml cylinder and was gently tapped to compact the flour to a constant volume. The density calculated with the initial volume was loose density while the final volume was used to obtain the bulk density (g cm<sup>-3</sup>) (Okaka and Potter, 1979).

### Swelling power

This was determined using the modified method of Adebowale and Lawal (2003). In a centrifuge tube, 1 g of the flour sample was mixed with 10 ml of distilled water, then heated at 80 °C for 30 min. This was shaken frequently while heating. The suspension was then centrifuged at 1000 xg for 15 min. The paste's weight was measured after the supernatant was decanted.

$$\text{Swelling power} = \frac{\text{Paste's weight}}{\text{Weight of dry flour}} \times 100$$

### Colour

Chroma Meter CR 300 (Konica Minolta, Japan) was used to gauge the colour of the samples. The samples' values for L\* (whiteness or blackness), a\* (redness or greenness), and b\* (yellowness or blueness) were noted. L\* values range from 100 for white to 0 for black; a\* values from + 60 for red to - 60 for green; and b\* values from + 60 for yellow to - 60 for blue.

### Pasting properties

A Rapid-visco-analyzer (RVA-4, Newport Scientific Pty. Ltd., Australia) was used to assess the pasting properties of the residue flours. Flour sample (1 % w/w dry weight basis) and water were mixed in the RVA canister to avoid lump formation and agitated at 960 rpm for 10 s. Thereafter, the test was completed at 160 rpm. The sample was kept at 50 °C for 1 min during the 13-minute heating and cooling cycle, which also

included heating the sample to 95 °C in 3 min 48 s, holding it for 2 min 30 s, cooling it to 50 °C in 3 min 50 s and maintaining at 50 °C for 1 min 52 s. Each sample was run in triplicate.

### Statistical Analysis

The data obtained were analysed using an independent sample student T-Test with SPSS (version 20.0) software.

## RESULTS AND DISCUSSION

This research studied the properties of residue flours obtained from two tigernut (*Cyperus esculentus* L.) varieties (yellow and brown). A total of eighteen (18) amino acids were detected in the tigernut residue flours as shown in Table 1. They consist of both essential and non-essential amino acids. Residue flour from yellow tigernut was significantly (p < 0.05) higher in leucine, isoleucine, phenylalanine, tryptophan, valine, methionine, proline, arginine, trypsin, histidine, cystine, glutamic acid, threonine, serine, and aspartic acid compared to brown variety which was significantly (p < 0.05) higher in lysine, alanine, and glycine. Glutamic acid had the highest concentration, 14% (YTRF) and 13% (BTRF) while cystine had the lowest concentration (1.7%, YTRF; 1.67%, BTRF) in the flours. Essential amino acids (EAA) were 48.6 and 56% for YTRF and BTRF, respectively. The ratio of EAA to non-essential amino acids (NEAA) was 0.94 and 1.24 for YTRF and BTRF, respectively. Leucine had the highest concentration (YTRF, 8.19%, and BTRF, 8%) while tryptophan had the lowest concentration (YTRF, 1.71% and BTRF, 1.67%) among the EAA of the residue flours. In quality terms, both YTRF and BTRF had high percentage of leucine, isoleucine, valine, and threonine compared to the FAO/WHO (1995) standard (Table 1). The percentage of lysine (4.89 and 5.37%) and tryptophan (1.39 and

1.31%) in the residue flours were also comparable to WHO/FAO standards (5.8% and 1.1%, respectively).

Table 1: Amino acid profile (g/100 g protein) of residue flours from yellow and brown varieties of tigernut

Amino acid	YTRF	% TAA	BTRF	% TAA	FAO/WHO std.
Leucine	5.63±0.04 <sup>a</sup>	8.19	5.17±0.02 <sup>b</sup>	8.00	6.6
Lysine	3.36±0.04 <sup>b</sup>	4.89	3.47±0.04 <sup>a</sup>	5.37	5.8
Isoleucine	4.09±0.04 <sup>a</sup>	5.95	3.73±0.04 <sup>b</sup>	5.77	2.8
Phenylalanine	3.38±0.01 <sup>a</sup>	4.91	3.19±0.01 <sup>b</sup>	4.93	6.3
Tryptophan	0.96±0.04 <sup>a</sup>	1.39	0.85±0.06 <sup>b</sup>	1.31	1.1
Valine	3.42±0.04 <sup>a</sup>	4.97	3.15±0.08 <sup>b</sup>	4.87	3.5
Methionine	1.18±0.02 <sup>a</sup>	1.71	1.08±0.01 <sup>b</sup>	1.67	2.5
Proline	3.30±0.07 <sup>a</sup>	4.80	3.10±0.07 <sup>b</sup>	4.80	
Arginine	5.20±0.06 <sup>a</sup>	7.56	4.60±0.18 <sup>b</sup>	7.12	
Trypsin	3.44±0.01 <sup>a</sup>	5.00	3.09±0.01 <sup>b</sup>	4.78	
Histidine	2.22±0.03 <sup>a</sup>	3.23	1.88±0.05 <sup>b</sup>	2.91	
Cystine	1.30±0.04 <sup>a</sup>	1.89	1.09±0.01 <sup>b</sup>	1.68	
Alanine	3.66±0.03 <sup>b</sup>	5.32	4.06±0.06 <sup>a</sup>	6.28	
Glutamic acid	9.69±0.01 <sup>a</sup>	14.10	8.51±0.16 <sup>b</sup>	13.17	
Glycine	4.15±0.11 <sup>b</sup>	6.03	4.53±0.04 <sup>a</sup>	7.01	
Threonine	3.24±0.01 <sup>a</sup>	4.71	3.09±0.10 <sup>b</sup>	4.78	3.4
Serine	3.64±0.04 <sup>a</sup>	5.29	3.54±0.01 <sup>b</sup>	5.48	
Aspartic acid	6.85±0.04 <sup>a</sup>	9.96	6.45±0.13 <sup>b</sup>	9.98	
Total	68.71±0.03		64.58±0.08		
TEAA		48.6		56.0	
TNEAA		51.4		44.0	
TEAA/TNEAA		0.94		1.24	

YTRF: Yellow tigernut residue flour, BTRF: Brown tigernut residue flour, WHO std: World Health Organization standard (% of total protein). TAA: Total Amino Acids, TEAA: Essential Amino Acids, TNEAA: Non-Essential Amino Acids. Values are means and standard deviations of triplicate determination. Values with the same superscript across the row are not significantly ( $p > 0.05$ ) different.

The amino acid composition of tigernut has been reported by many researchers but the information is scanty on the amino acid profile of tigernut residue flour. Glew *et al.* (2006) reported the presence of eighteen (18) amino acids, Aremu *et al.* (2015) reported seventeen (17) while Bosch *et al.* (2005) reported fifteen (15) amino acids for whole tigernut flour. Glew *et al.* (2006) and Aremu *et al.* (2015) reported glutamic acid as the amino acid with the highest concentration and cystine with the lowest concentration while for Bosch *et al.* (2005), arginine was the highest followed by glutamic acid. The eight (8) essential amino acids detected in tigernut residue

flours have also been detected in tigernut at varying concentrations by these authors.

The proportion of Total Essential Amino Acids (TEAA) in the residue flours (48.6 and 56%) compares favourably with other sources such as 42.6% for Kersting's groundnut flour (Ikujenlola *et al.*, 2022) and 50% for egg (FAO/WHO, 1991). The values also surpass the recommended 39% for infants, 26% for children and 11% for adults by FAO/WHO/UNU (2013). The high quality of the essential amino acids in tigernut residues suggests that the flour can be used as a substitute (whole or

partial) for wheat flour in formulating food for infants, children, and adults.

Fourteen phenolic compounds were detected in the residue flours (Table 2). Five phenolic compounds (apigenin, naringenin, kaempferol, benzoic acid and chrysin) present in YTRF were absent in BTRF while six phenolic compounds (ferulic acid, luteolin, quercetin, syringic acid, vanillic acid and p-coumaric acids) were present in BTRF but absent in YTRF. Three phenolic compounds namely caffeic acid, gallic acid, and phenylacetic acid, were common to the two residue flours though at different concentrations. Phenylacetic acid (68.66 mg/100 g)

and caffeic acid (56.13 mg/100 g) were the highest while chrysin (0.03 mg/100 g) and p-coumaric acid (0.29 mg/100 g) were the lowest in concentration in YTRF and BTRF, respectively.

To the best knowledge of the authors, this is the first report on the phenolic profile of tigernut residues. The phenolic compounds detected in the tigernut residue flours have been reported in whole tigernut flour (Oladele *et al.*, 2017) and their products (Babiker *et al.*, 2021). Phenolic compounds such as caffeic acid and Quercetin are bioactive compounds with antioxidant activity (Apeah-Bah *et al.*, 2017).

Table 2: Phenolic compounds profile and concentration (mg/ 100 g) in residue flours from yellow and brown varieties of tigernut (*Cyperus esculentus*)

S/No	Retention time (Min)	Phenolic compound	YTRF	BTRF
1	0.54	Gallic acid	0.97±0.01	0.32±0.01
2	1.43	Syringic acid	ND	1.07±0.03
3	1.62	Caffeic acid	29.33±1.59	56.13±2.50
4	2.57	Ferulic acid	ND	39.51±2.75
5	2.72	Vanillic acid	ND	38.81±1.89
6	2.97	Luteolin	ND	11.70±0.70
7	3.30	Quercetin	ND	48.64±3.47
8	3.97	Benzoic acid	28.32±1.68	ND
9	4.54	p-coumaric acid	ND	0.29±0.02
10	4.63	Phenylacetic acid	68.66±4.20	3.31±0.26
11	6.26	Apigenin	6.65±0.13	ND
12	6.98	Naringenin	0.28±0.00	ND
13	9.57	Kaempferol	0.05±0.00	ND
14	9.81	Chrysin	0.03±0.00	ND

Values are means with standard deviations. YTRF – residue flour from yellow variety of tigernut; BTRF - residue flour from brown variety of tigernut; ND – Not detected.

The flavonoid and phenolic content of the flours ranged from 0.32 - 0.91 mg GAE/ g and 1.26 – 1.30 mg GAE/ g, respectively as shown in Figure 1. The flavonoid content was significantly ( $p < 0.05$ ) higher in YTRF compared to BTRF whereas the total phenolic content (TPC) was not significantly ( $p > 0.05$ ) different between the two samples. Similarly, FRAP was significantly higher in YTRF (3.43 AAE/ g) than in BTRF (1.41 AAE/ g).

The TPC (1.26 – 1.30 mg GAE/ g) of the residue flours was comparable to 0.8 – 1.4 mg GAE/ g reported for artichoke waste but lower than 55.6 mg GAE/ g for lemon residue (Patrón-Vázquez *et al.*, 2019) and 56.2 mg GAE/ g for mango waste (Panzella *et al.*, 2020). Phenolic compounds including flavonoids exhibit

antioxidant property. A higher concentration of phenolic compounds exhibits higher antioxidant activity (Adarkwah-Yiadom and Duodu, 2017). Although the TPC values of the residue flours were not significantly different ( $p > 0.05$ ) between the two samples, the higher flavonoid content of YTRF might be responsible for the higher antioxidant activity. The results suggest that flavonoids could play a vital role in the antioxidant activity of the residue flours. Flavonoids, apart from conferring colour, can inhibit enzymes, act as chelating agents and protect cells against some radicals. This can be related mainly to the antioxidant activity of the compounds (Hargrove *et al.*, 2011).

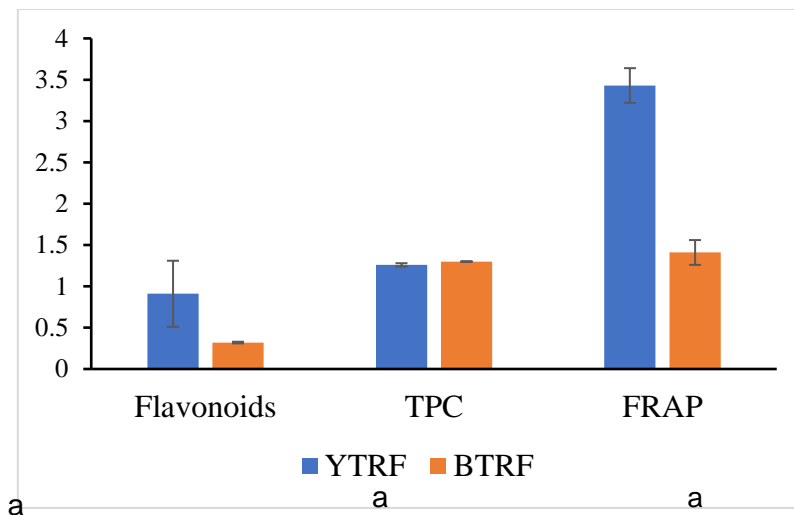


Figure 1: Flavonoid content, total phenolic content, and antioxidant property of residue flours from yellow and brown varieties of tigernut. YTRF: Yellow tiger nut residue flour, BTRF: Brown tiger nut residue flour. Flavonoids-mg/ 100 g sample, TPC–Total phenolic content (mg Gallic acid equivalent, GAE/ g), FRAP– Ferric reducing antioxidant property (AAE/ g). Values are means of triplicate determinations with standard deviations. Samples with different superscripts are significantly ( $P < 0.05$ ) different

The techno-functional properties, colour and pasting properties of the tigernut residue flours are shown in Table 3. There was no significant difference ( $p > 0.05$ ) in the water absorption capacity, foam capacity, foam stability, loose and packed bulk density, and swelling capacity of the tigernut residue flours. However, YTRF had significantly ( $p < 0.05$ ) higher oil absorption capacity ( $3.40 \pm 0.0$  ml/g compared to BTRF ( $2.90 \pm 0.1$  ml/g).

Table 3: Techno-functional, colour, and pasting properties of yellow and brown tiger nut residue flours

Property	YTRF	BTRF
Water absorption capacity (ml/ g)	$3.99 \pm 0.29^a$	$3.53 \pm 0.42^a$
Oil absorption capacity (ml/ g)	$3.40 \pm 0.00^a$	$2.90 \pm 0.10^b$
Foam capacity (%)	$14.00 \pm 2.00^a$	$13.33 \pm 2.31^a$
Foam stability (%)	$2.67 \pm 1.15^a$	$2.67 \pm 1.10^a$
Loose bulk density (g/ cm <sup>3</sup> )	$0.23 \pm 0.02^a$	$0.21 \pm 0.15^a$
Packed bulk density (g/ cm <sup>3</sup> )	$0.34 \pm 0.02^a$	$0.33 \pm 0.01^a$
Swelling power	$6.13 \pm 0.15^a$	$5.77 \pm 0.31^a$
L*	$63.78 \pm 0.49^a$	$50.03 \pm 0.42^b$
a*	$-1.97 \pm 0.01^b$	$0.06 \pm 0.01^a$
b*	$15.61 \pm 0.15^a$	$13.88 \pm 0.18^b$
Peak viscosity (RVU)	$589 \pm 99^a$	$527 \pm 30^a$
Trough viscosity (RVU)	$499 \pm 68^a$	$412 \pm 22^a$
Breakdown viscosity (RVU)	$90 \pm 31^a$	$115 \pm 52^a$
Final viscosity (RVU)	$786 \pm 1^a$	$789 \pm 2^a$
Setback viscosity (RVU)	$336 \pm 0.1^a$	$377 \pm 2.4^a$
Peak time (Min)	$6.97 \pm 0.1^a$	$5.77 \pm 0.2^b$
Pasting temperature (°C)	$94.95 \pm 0.2^a$	$94.08 \pm 1.7^a$

YTRF: Yellow tiger nut residue flour, BTRF: Brown tiger nut residue flour, L\*: Lightness, a\*: redness or greenness, b\*: yellowness or blueness, RVU – Rapid analyser unit. Values are means and standard deviations of triplicate determinations. Values with the same superscript across the row are not significantly ( $p > 0.05$ ) different

Limited reports are available on the functional properties of tigernut residue flours. The water absorption capacity values ( $3.53$  and  $3.99$  ml/ g) obtained for the residue flours were higher compared to  $1.79$ ,  $1.42$ ,  $2.91$ , and  $3.17$  ml/ g reported for tigernut, soybean, wheat, and maize hulls dietary fibres, respectively (Sanchez-Zapata *et al.*, 2009). The values are however lower compared to some other vegetable wastes (Carrot,  $6.36$  and sugar beet,  $6.04$  ml/ g) (Sanchez-Zapata *et al.*, 2009).

Water absorption capacity describes flour behaviour in the presence of a moisture. This can be influenced by the structure and composition of a material, the amount of total protein, and soluble dietary fibre (Sanchez-Zapata *et al.*, 2009). Tigernut residue is low in protein and probably soluble dietary fibre (Aremu *et al.*, 2015). The low water absorption capacity of the residue flours could be due to the low protein and low soluble dietary fibre content. The results of the present study suggest that tiger nut residue flour may find

application in baked products that require a little amount of water such as cookies.

Various researchers have reported on the functional properties of tigernut but not on tigernut residues. Ayo *et al.* (2016) reported that there was no significant ( $p > 0.05$ ) difference in the loose and packed bulk density, and water absorption capacity of black and brown varieties of tigernut. Packed bulk density is a measure of the heaviness of a flour sample. The packed bulk density suggests the heaviness of the residue flours and their suitability for use as thickeners in the formulation of complementary foods.

There was a significant difference ( $p < 0.05$ ) in the YTRF (3.4 ml/g) and BTRF (2.9 ml/g) oil absorption capacity values. The values were higher than those reported by Ismaila *et al.* (2020) (1.04 and 1.13 ml/g) and Oladele and Aina (2007) (1.07 and 1.13 ml/g) for whole tigernut flours.

There was no significant difference ( $p > 0.05$ ) in the foam capacity of YTRF (14%) and BTRF (13.3%). The foam capacity values obtained in this work were higher than the values of 10.23 and 10.90% reported by Ismaila *et al.* (2020) and 10.28 and 11.07% reported by Oladele and Aina (2007). The high foam capacity could be associated to the high protein content of the flour since foamability is related to the amount of solubilized protein. There was no significant difference ( $p > 0.05$ ) in the foam stability of YTRF (2.67%) and BTRF (2.67%), the values obtained were lower compared to the values (50.60 and 58.99%) reported for whole tigernut flours (Oladele and Aina, 2007).

Swelling power connotes the expansion accompanying spontaneous uptake of solvent (Lawal and Adebawale, 2005). There was no significant difference ( $p > 0.05$ ) in the swelling power of YTRF (6.1%) and BTRF (5.7%), but the values were higher than those obtained by Ismaila *et al.* (2020). Adebawale and Lawal (2003) reported that swelling causes changes in the hydrodynamic properties of food thus impacting characteristics such as body thickening and increased viscosity.

YTRF had significantly ( $p < 0.05$ ) higher  $L^*$  and  $b^*$  values and lower  $a^*$  value compared to BTRF as shown in Table 4. Colour is an important quality in consumer acceptability of a product (Coskuner *et al.*, 2002). The colour of a food material can be influenced by the pigments and structural composition of the food (López-marcos *et al.*, 2015). Flour colour seldom affects the colour of products and contributes to the acceptability of products by end-users. Generally, consumers desire bright white colour flour for many products. The higher  $L^*$  and  $b^*$  values of YTRF corroborate the physical yellow colour compared to BTRF which is brownish and darker in colour. The colour of tigernut residue flours suggests that they

could contribute to the acceptability of foods without significant changes in the colour of the food.

The peak, trough, breakdown, final and setback viscosity, peak time, and pasting temperature ranged from 527 – 589 RVU, 412 – 499 RVU, 90 – 115 RVU, 786 – 789 RVU, 336 – 377 RVU, 5.77 – 6.97 min and 94.08 – 94.95 °C, respectively. The residue flours were not significantly ( $p > 0.05$ ) different in peak, trough, breakdown, final, setback viscosity, and pasting temperature, but the peak time of YTRF was significantly different from that of BTRF. The peak viscosity values of the tigernut residue flours were higher than those reported by Iwe *et al.* (2017) for high-quality cassava flour (62 -199 RVU), Falade and Okafor (2015) for cocoyam flour (97 – 201 RVU), Iwe *et al.* (2016) for rice flour (245 RVU), African yam bean flour (225 RVU), and Eke-Ejiofor and Oparaodu (2019) for millet flours (117 – 382 RVU). Peak viscosity is the maximum swelling limit of starch paste before disintegration (Hoover, 2001), and also depicts the swelling strength of starch under a limited supply of moisture during cooking (Olayinka *et al.*, 2008). High peak viscosity is an indication of high starch content (Iwe *et al.*, 2016) or high fibre content (Oladiran and Emmambux, 2017), and also indicates weak cohesion among starch granules. The high peak viscosity of the tigernut residue flours could be related to the dietary fibre content of the flours since fibre-rich flours have higher peak viscosity than flour with low fibre content (Oladiran and Emmambux, 2017). The pasting properties of flour can be influenced by preparation methods (Falade and Okafor, 2015). Preparation of tigernut residue involves a reduction in the starch content of tigernut (Agboola *et al.*, 2018). The reduction in starch content leading to an increase in fibre content might contribute to the high peak viscosity of the residue flours.

Breakdown viscosity is the difference between the peak and the trough viscosity. It is a measure of the resistance of starch paste to disintegration during heating and shearing (Lawal and Adebawale, 2005). It also depicts the stability of starch paste and its ability to withstand shear stress (Ocheme *et al.*, 2018). The present results indicate that tigernut residue flour pastes had low resistance to shearing force.

The ability of a starch-based flour to form a viscous paste/gel after cooking and cooling is known as the final viscosity while the tendency of the paste/gel to retrograde after cooking and cooling refers to setback viscosity. Tigernut residue flours showed higher final viscosity relative to other flours (Falade and Okafor, 2015; Iwe *et al.*, 2016, 2017). The residue flours also displayed high setback viscosity. Tigernut starch has been shown to have high setback viscosity (Agboola *et al.*, 2018). Setback viscosity is an important parameter used to determine the quality of flours. After cooling of starch paste, the disrupted amylose component tends to re-associate resulting in

retrogradation. The result of the present study suggests that tigernut residue flour can be incorporated into stiff paste products.

Peak time, defined as the time to reach peak viscosity, is an important parameter in the cooking property of any starch-based system. Peak time is a measure of the cooking time of a starch-based system. Low peak time characterizes the fast swelling of starch granules in the flour. Both YTRF and BTRF are not significantly different in pasting temperature. This suggests that the two flours would require almost the same energy to cook but BTRF would cook faster than YTRF.

## Conclusion

Varietal effect seems to be minimal on most of the examined properties of tigernut residue flours. Tigernut residue flours are rich in essential amino acids, phenolic compounds, and moderate in antioxidant activity suggesting their potentials as food nutrition improver. The functional and pasting properties also suggest that tigernut residue flours can be incorporated in many foods such as cookies. Tigernut residue flours could be used to enhance the nutritional status of the poor and the vulnerable especially in the area of production. Incorporation of tigernut residues in food products could help in reducing malnutrition and enhance food security. It is recommended that further work be done on suitability of residue flours in food production.

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