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Functional and Chemical Properties of Flour from Selected Cassava (*Manihot esculenta* Crantz) Varieties Used as Beef Sausage Fillers

***Oshibanjo, Debola Olusegun**
Department of Animal Production, University of Jos, Jos, Plateau State, Nigeria
Corresponding author: oshibanjoo@unijos.edu.ng
ORCID ID: https://orcid.org/0000-0001-5619-5925

Muamba, Kashala Eric
Department of Crop Production, University of Jos, Jos, Plateau State, Nigeria
muambak@unijos.edu.ng
ORCID ID: https://orcid.org/0009-0003-2619-9521

Adekeye, Adetayo Bamikole
International Livestock Research Institute, Ibadan, Oyo State, Nigeria
adetayo.adekeye@ilri.cgiar.org
ORCID ID: https://orcid.org/0000-0003-4890-8942

Adediran, Opeyemi Adewumi
Department of Animal Science, University of Ibadan, Ibadan, Oyo State, Nigeria
o.adediran@mail.ui.edu.ng
ORCID ID: https://orcid.org/0000-0001-9595-2319

Mfon, Sunday Johnson
Department of Animal Production, University of Jos, Jos, Plateau State, Nigeria
ORCID ID: https://orcid.org/0009-0007-5390-7457

Adi, Florence Dongjab
Department of Animal Production, University of Jos, Jos, Plateau State, Nigeria
ORCID ID: https://orcid.org/0009-0007-6723-0635

Abstract

Objective: The study aimed to compare the functional and chemical properties of flour derived from selected cassava (*Manihot esculenta* Crantz) varieties intended for use as fillers in beef sausage. The research evaluated how specific improved cultivars differ in nutritional and physical characteristics to determine their suitability for both human food and animal feed applications.

Method: Freshly harvested tubers from high-yielding, low-cyanide improved cultivars—specifically TME 419, TMS 01/1368, TMS 98/0505 (yellow), and TMS 30572—were obtained for processing. The study utilised standard procedures to evaluate a wide range of parameters, including functional properties (bulk density, pH, and emulsion activity), amino acids, fatty acids, mineral composition, and proximate analysis.

Result: Analysis revealed that TME 419 possessed the highest bulk density (0.68 g/cm³), while TMS 30572 had the highest pH (6.23) and TMS 01/1368 the lowest (6.13). TMS 98/0505 (yellow) exhibited significantly higher emulsion activity (10.16%) and was the only variety to contain Omega-3 fatty acids. While proximate analysis showed no significant differences among varieties, TMS 98/0505 (yellow) had the highest crude protein, ash, and fibre contents. This yellow variety also had the highest concentrations of sodium, potassium, calcium, and zinc. In contrast, TME 419 contained the highest ferric iron concentration (1,143.11 ppm), and TMS 30572 had the highest phosphorus concentration (3,522.05 ppm).

Conclusion: The study reveals significant varietal differences in flour properties, indicating potential for diverse end-use applications. TMS 98/0505 (yellow) stands out as a superior filler due to its high ash, crude protein, fibre, and mineral composition. These findings suggest that although all varieties are viable, the yellow TMS 98/0505 variety offers enhanced nutritional value for fortifying beef sausage and broader use in the food and feed industries.

Keywords: Functional properties, cassava flour, varieties, amino acid, fatty acid and mineral composition

Introduction

Cassava (*Manihot esculenta*) is a root crop consumed worldwide. It is drought-tolerant, can withstand harsh climatic conditions, and thrives on poor soils and marginal lands (Ezui et al*.,* 2018). Cassava is the primary dietary source of energy for the majority of people living in the lowland tropics and much of the subhumid tropics of West and Central Africa. Cassava is second only to cereals in importance as a global source of carbohydrates. However, cassava is the second most important tropical root crop in West Africa (Adisa et al*.,* 2015; Falola et al*.,* 2017). Cassava root is a starchy crop that has been processed into various forms for utilisation. For example, it may be processed into high-quality cassava flour (HQCF). HQCF is an unfermented cassava product that has been successfully used as a partial and complete replacement for wheat flour in the processing of bread, cookies, and other confectionery products (Maziya-Dixon et al*.,* 2017).

Cassava storage roots have a short shelf life due to postharvest physiological deterioration that occurs shortly after harvesting (Ayetigbo, 2019). It causes root discolouration, making them unsuitable for consumption or for use as a raw material in the food industry. Moreover, the presence of hydrogen cyanide (HCN) in roots limits its usage in the food industry. Proper storage conditions have not yet been developed to overcome the high postharvest losses of cassava roots. Immediate channelling of harvested storage roots into value-added products is worth considering to maximise their utilisation. Making flour is one of the best ways to prevent a short shelf life.

However, certain properties of cassava flour and starch, including physical, chemical, and physicochemical parameters, as well as pasting and thermal properties, are important for their use in the food industry. Moreover, some functional characteristics have been reported to be correlated with key qualities of products produced from such flours (Linlaud et al., 2009).

Therefore, this study sought to evaluate the functional and chemical properties of flour from selected cassava (*Manihot esculenta Crantz*) Varieties**.**

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Material and Methods

Some freshly harvested white cassava tubers and yellow cassava tubers were obtained from the High-yielding, low-cyanide cassava roots of improved cultivar TME 419, TMS 01/1368, TMS 98/0505 (yellow), and TMS 30572 were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Other materials for the study were obtained from the Animal Products and Processing Laboratories of the Departments of Animal Production, Faculty of Agriculture, University of Jos, Plateau State. The study was carried out.

Flour production

Cassava roots (2 kg) were peeled manually with a stainless-steel knife, washed with 25 litres of potable water to remove adhering soil, sliced into small pieces, and then sun-dried for 5 days. Dried samples were milled, sieved (sieve size: 180 µm), and then packaged in Ziplock bags prior to analyses.

Functional Properties

Functional properties were evaluated according to Bera et al. 1989 as modified by Odedeji and Oyeleke (2011).

Bulk density

Fifty grams of flour sample was placed into a 100ml measuring cylinder. The cylinder was gently tapped several times until a constant reading was achieved, according to the procedure of Sosulski et al. (1987), as modified by Odedeji and Oyeleke (2011). The volume of the sample is recorded as:

$$\text{Bulk density (g/cm3)} = \frac{Weight\ of\ sample}{Volume\ of\ sample\ tapped\ after\ tapping}$$

Water absorption capacity

15mL of distilled water was added to 1g of flour in a weighed 25mL centrifuge tube, and the tube was agitated in a vortex mixer for 2 minutes. It was centrifuged at 4000 rpm for 20 min. The clear supernatant was decanted and discarded. The adhered water droplets were removed, and the sample was reweighed. Water absorption capacity was expressed as the weight of water bound by 100g of dried flour as a percentage of the flour weight.

Oil absorption capacity

Ten mL of refined corn oil was added to 1g of the flour in a 25 or 80-mL centrifuge tube. The tube was agitated on a vortex mixer for 2 minutes. It was centrifuged at 4000rpm for 20minutes. The volume of free oil was recorded, and the fat absorption capacity was expressed as millilitres of oil bound by 100g dried flour as a percentage of the flour weight.

Water and oil retention

Four grams of the sample were weighed, and 20mL of water or peanut oil was added to a 30 30mL centrifuge tube. This was stirred occasionally with a glass rod for 30 minutes. It was centrifuged at 4000 rpm for 20minutes. The volume of decanted fluid (water or peanut oil) was measured.

Emulsion Activity

Two grams of the sample were blended with 25 mL of distilled water for 30 seconds at 1600 rpm in a blender. After complete dispersion, the refined oil was separated into two burettes and blended until a two-layer separation occurred; the water-fat emulsifying capacity was expressed as the amount of oil emulsified by 1g of flour.

$$\text{Emulsion Activity \%} = \frac{\text{Height of emulsified layer}}{\text{Height of total concentration in the cylinder}} \text{x } 100$$

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Proximate, amino acid, fatty acid and mineral determination

Spectral data were recorded over 1100-2500 nm using a FOSS NIR System 2500 scanning monochromator infrared spectrophotometer. The signals were recorded as log(1/R) using an IBM-compatible computer at the International Livestock Research Institute laboratory. Samples were scanned and predicted for chemical composition (dry matter, crude protein, crude fiber, ash, fat, starch, neutral detergent fiber, acid detergent fiber, and acid detergent lignin) and mineral profile (Na, K, Ca, P, Mg, Cu, Fe), metabolizable energy, and in vitro, organic matter digestibility of the samples were assessed using the equation for the feed sample analysis based on the mixed feed global calibration model using the software package (Win ISI II FOSS, Denmark, Model NIRS™ 5000) calibrated against convectional wet laboratory analysis. Spectral data were recorded in the wavelength range of 1100-2500nm using the NIR system mode 2500 scanning monochromatic infrared spectrophotometer. The software for scanning, mathematical processing, and statistical analysis was included with the spectrophotometer. Calibration models for amino acids and fatty acids were developed using NIR spectra collected on a FOSS NIRSystems DS2500 (1100–2500 nm) and reference laboratory methods (HPLC for amino acids; GC for fatty acids). Partial least squares regression with optimised preprocessing was applied in the WinISI software. Successful calibrations exhibited high coefficients of determination (R^2cal> 0.99) and validation R^2pred > 0.85 for most analytes. Standard errors of prediction (SEP) were low relative to the analyte standard deviations (RPD > 3 for major fatty acids; R^2pred ~ 0.80–0.94 for key amino acids), indicating robust predictive performance for quantitative analysis.

Results

Figure 1 and 2 shows the Bulk density, pH, emulsion activities, water retention, water absorption capacity, oil retention and oil absorption properties of selected cassava flour. Bulk density was higher in TME 419 (0.68g/cm^3) compared with others. TMS 30572 had the highest pH (6.23), whereas the lowest pH was in the TMS 01/1368 variety (6.13). Emulsion activities were significantly higher in TMS 98/0505 (yellow), 10.16%, with the least emulsion activities in TMS 01/1368. (5.71%).

Water retention was lower in TMS 01/1368, whereas it was higher in both TME 419 and 30572 varieties. Water absorption capacity was significantly higher in TME 01/1368, whereas TME 01/1368 exhibited the lowest water absorption. Oil retention was significantly higher in cassava TMS 30572, whereas the lowest value was observed in TME 419. Oil absorption capacity was higher in TME 30572 cassava flour than in TMS 01/1368.

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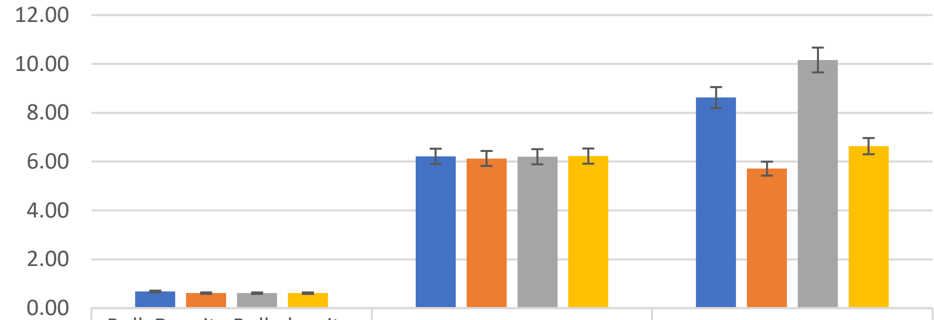
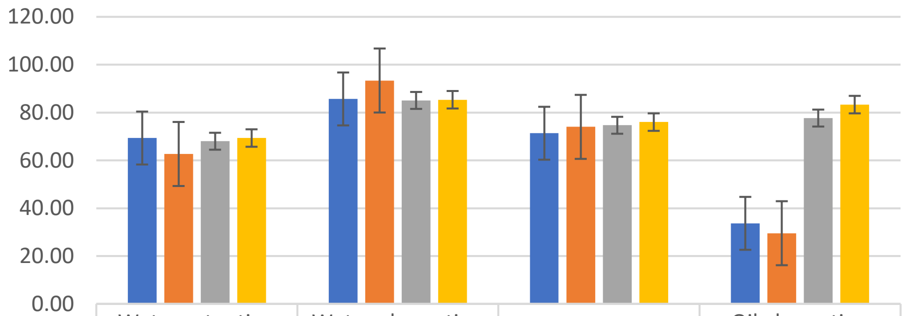


	Bulk Density Bulk density (g/cm3)	pH	Emulsion activities (%)
TME 419	0.68	6.22	8.62
TMS 01/1368	0.61	6.13	5.71
TMS 98/0505 (yellow)	0.61	6.20	10.16
TMS 30572	0.61	6.23	6.63

TME 419 TMS 01/1368 TMS 98/0505 (yellow) TMS 30572

Figure 1: Bulk density, pH and emulsion activities of selected cassava flour



	Water retention (%)	Water absorption capacity (%)	Oil retention (%)	Oil absorption capacity (%)
TME 419	69.33	85.68	71.33	33.66
TMS 01/1368	62.67	93.39	74.00	29.55
TMS 98/0505 (yellow)	68.00	85.06	74.67	77.68
TMS 30572	69.33	85.34	76.00	83.31

TME 419 TMS 01/1368 TMS 98/0505 (yellow) TMS 30572

Figure 2: Water retention, water absorption capacity, oil retention and oil absorption properties of selected cassava flour

Table 1 shows the proximate analysis of selected cassava flours. Although there were no significant differences across the proximate analyses, TMS 98/0505 (yellow) cassava had the highest crude protein, ash, and fibre content compared with other cassava varieties. A similar result was obtained in the amino acid and fatty acid in Tables 2 and 3, respectively. However, omega-3 was detected only in TMS 98/0505 (yellow), whereas it was absent in TME 419, TMS 01/1368, and TMS 30572.

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Table 1: Proximate Analysis of Selected Cassava Flours

Parameters	**TME 419**	**TMS 01/1368**	**TMS 98/0505 (yellow)**	**TMS 30572**	**SEM**	***P-value***
Dry matter %	92.19	92.68	92.38	92.13	0.25	0.905
Ash	0.05	0.23	1.57	-0.16	0.31	0.279
Crude protein %	3.02	3.04	4.01	3.89	0.28	0.503
Fat %	2.13	2.32	2.22	2.44	0.25	0.983
Fibre %	4.30	4.45	4.56	4.07	0.25	0.936
Neutral detergent fibre (dm%)	41.65	41.59	40.24	40.10	0.31	0.177
Acid detergent fiber(dm%)	10.24	10.24	9.48	8.68	0.25	0.251
Acid detergent lignin (dm%)	3.65	3.90	3.50	3.37	0.25	0.923
Metabolizable energy (mj/kg)	10.16	10.07	10.07	10.12	0.25	0.996
In vitro, organic matter digestibility (om%)	65.55	64.99	66.09	65.28	0.27	0.601

SEM- Standard error mean

Table 2: Amino Acid Profile of Selected Cassava Flours

Parameters % (Gms/100Gms)	**TME 419**	**TMS 01/1368**	**TMS 98/0505 (yellow)**	**TMS 30572**	**SEM**	***P-value***
Aspartic acid	0.45	0.44	0.61	0.47	0.25	0.996
Serine	0.13	0.14	0.13	0.18	0.25	1.000
Glutamic acid	0.06	0.16	0.12	0.31	0.25	0.991

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Parameters % (Gms/100Gms)	TME 419	TMS 01/1368	TMS 98/0505 (yellow)	TMS 30572	SEM	*P-value*
Glycine	nd	nd	nd	nd		
Histidine	0.32	0.32	0.3	0.34	0.25	1.000
Arginine	0.5	0.52	0.52	0.58	0.25	1.000
Threonine	0.11	0.11	0.1	0.14	0.25	1.000
Alanine	0.27	0.24	0.31	0.29	0.25	1.000
Proline	nd	nd	nd	nd		
Cystine	0.12	0.13	0.11	0.13	0.25	1.000
Tyrosine	0.02	0.04	0.05	0.06	0.25	1.000
Valine	0.08	0.09	0.1	0.13	0.25	1.000
Methionine	nd	nd	nd	nd		
Lysine	0.18	0.18	0.18	0.18	0.25	1.000
Isoleucine	nd	nd	nd	nd		
Leucine	0	0.02	0.03	0.08	0.25	1.000
Phenylalanine	0.03	0.05	0.07	0.08	0.25	1.000
Tryptophane	nd	nd	nd	nd		-

nd – Not detected

SEM- Standard error mean

Table 3: Fatty acid profile of selected cassava flours

Parameters	TME 419	TMS 01/1368	TMS 98/0505 (yellow)	TMS 30572	SEM	*P-value*
Omega-3	nd	nd	53.39	nd		
Omega-6	nd	nd	nd	nd		
Trans-fatty acid	6.16	6.59	5.56	6.41	0.27	0.630
Saturated fatty acid	nd	nd	nd	nd		

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Parameters	**TME 419**	**TMS 01/1368**	**TMS 98/0505 (yellow)**	**TMS 30572**	**SEM**	***P-value***
Monounsaturated fatty acid	nd	nd	nd	nd		
Polyunsaturated fatty acid	nd	nd	nd	nd		

nd – Not detected

SEM- Standard error mean

Mineral composition of selected cassava flours is shown in Table 4. Sodium, potassium, calcium, and zinc were significantly higher in TMS 98/0505 (yellow): 1,719.84, 10,917.01, 2,308.14, and 36.12 PPM, respectively, whereas the lowest values were in TME 419 cassava: 1,426.42 (sodium), 9,969.60 (potassium), 1,203.07 (calcium), and 2,853.20 (phosphorus), respectively. Ferric was higher in TME 419 (1,143.11) while phosphorus was higher in TMS 30572 (3,522.05 ppm).

Table 4: Mineral Composition of Selected Cassava Flours

Parameters (PPM)	**TME 419**	**TMS 01/1368**	**TMS 98/0505 (yellow)**	**TMS 30572**	**SEM**	***P-value***
Sodium	1,426.42^{d}	1,431.67^{c}	1,719.84^{a}	1,387.45^{b}	40.00	0.000
Potassium	9,969.60^{d}	10,414.88^{b}	10,917.01^{a}	10,296.05^{c}	102.64	0.000
Magnesium	Nd	Nd	Nd	Nd		
Calcium	1,203.07^{d}	1,423.32^{b}	2,308.14^{a}	1,211.54^{c}	136.93	0.000
Manganese	2.54	2.92	36.45	Nd	5.63	
Ferric	1,143.11^{a}	1,067.38^{c}	1,100.81^{b}	973.44^{d}	18.84	0.000
Copper	6.26	6.47	7.81	7.19	0.31	0.286
Zinc	28.28^{c}	29.98^{bc}	36.12^{a}	31.50^{b}	0.91	0.000
Phosphorus	2,853.20^{d}	3,410.12^{c}	3,488.53^{b}	3,522.05^{a}	81.92	0.000

^{abc}... Means on the same row with different superscripts are significantly different ($P<0.05$)

nd – Not detected

SEM- Standard error mean

Discussion

The BDs of the four flour samples were not significantly different (Figure 1). Klang et al (2020)., Dereje et al. (2020) and Anosike et al. (2020) reported that flours with a BD lower than 1 g/mL can be used in the manufacture of low-bulk weaning foods and high-energy foods. In addition, it facilitates storage, transport, and marketing because the packaging material required to store the flours is minimal (Dereje et al., 2020). According to Onyeneke (2019), a higher bulk density is desirable to facilitate flour dispensing. Hence, an increase in bulk density increases the sinkability of powdered particles, thereby facilitating wetting by enhancing their dispersion. TMS 30572 cassava had the highest pH (6.23), whereas the TMS 01/1368 variety had the lowest (6.13). This could be due to the lower acidity in the cassava flour.

Emulsion activities (EA) relate to the ability of flour to bind water and fat together and are influenced by protein solubility. TMS 98/0505 (yellow) cassava had significantly higher EA values than other flours. There is a positive correlation between protein content and EA (Nilusha et al., 2021). This is consistent with the present results, as TMS 98/0505 (yellow) exhibited high EA and protein content, potentially due to strong protein adsorption at the oil-water interface. Water retention is the ability of flour to retain water, potentially due to protein solubility; it was lower in TMS 01/1368 and higher in TME 419 and 30572. Oil retention may be influenced by bulk density and moisture content (Oshibanjo, 2017). Higher WACs may be attributed to starch crystal destruction (Lu. et al., 2020), granule architecture, amylose, amylopectin, or polar amino residues with high water affinity (Godswill, 2019). High WACs (>100%) facilitate food processing and dough handling (Jisha et al., 2010). Oil absorption capacity (OAC) improves mouthfeel and flavour retention. Low protein content is expected to be associated with low OACs, as protein has a positive relationship with OAC (Godswill, 2019). OAC involves protein-fat interactions (Lu et al., 2020), physical binding via capillary attraction, and protein hydrophobicity (Dereje et al., 2020), all of which enhance palatability (Jisha et al., 2010).

Proximate parameters showed no significant difference. Moisture content is vital for shelf life (Onyeneke, 2019). All samples were below the recommended 13% limit (Codex Alimentarius Commission, 1995), suggesting stability if stored with proper moisture barriers (Bolaji et al., 2021). Ash content (0.05–1.57%) reflects inorganic mineral content, with TMS 98/0505 (yellow) having the highest values, consistent with Tambo et al. (2019) and Dudu et al. (2020), possibly due to beta-carotene. Protein content (3.04–4.01%) was higher than reported by Tambo et al. (2019) and Dudu et al. (2020). Fat and fibre results differed from those reported by Oladunmoye et al. (2014) and were higher than those reported by Oyeyinka et al. (2019). Low-fat content (<1%) reduces susceptibility to starch-lipid complexes, resulting in low swelling and solubility (Huang et al., 2020), and thereby facilitates low-fat formulations. Fibre fraction, metabolizable energy, and digestibility showed no significant differences and were lower than those of Tambo et al. (2019) and Dudu et al. (2020). NDF predicts the slow degradation of fibre and correlates with digestion (Hall, 2000). NDF in these products was higher than Hall's (2000) maize value but within the range for cassava peel reported by Heuze et al. (2016). Lignins are insoluble cell wall compounds that can limit digestibility, but may reduce the risk of heart disease by binding cholesterol.

Aspartic acid was lower than reported by Aro and Aletor (2012) and Bayata (2019). Glutamic acid was the most abundant amino acid, consistent with McDonald et al. (2010) and Omode et al. (2018). Glycine is non-essential (Moore & Langley, 2008) but essential in chicks (McDonald et al., 2010), serving as a precursor for purine and porphyrins (Moore & Langley,

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2008). Glycine lacks stereoisomers, and its requirement in chicks increases with low levels of other nutrients (McDonald et al., 2010). Histidine is affected by pH changes (Moore & Langley, 2008); its maize and wheat bran levels (Evonik, 2015) and cassava root and peel values (Bayata, 2019) were higher than those in this study. Arginine has anti-inflammatory properties (Birmani et al., 2019) and is vital for growth (Geng et al., 2011). Alanine and glutamine transport amino groups to the liver (Dalibard et al., 2014), with alanine levels here lower than those reported by Aro and Aletor (2012) and Bayata (2019). Proline-rich proteins may mitigate tannin effects in ruminants, but poultry have limited proline-rich protein synthesis (McDonald et al., 2010). Methionine is the first limiting amino acid required for metabolic reactions, while lysine is a second-limiting amino acid (Dalibard et al., 2014) that improves weight gain. Lysine here was similar to that of *Solanum tuberosum* (Blair, 2008) but lower than that of Bayata (2019). Isoleucine is ketogenic and glucogenic (Moore & Langley, 2008) and was lower than unfermented peels (Aro & Aletor, 2012). Leucine was lower than Aro and Aletor (2012). Phenylalanine can make tyrosine non-essential (Moore & Langley, 2008) and is required for growth (McDonald et al., 2010). Phenylalanine and tyrosine are building blocks of catecholamines; deficiency of the enzymes that catalyse their breakdown causes hyperphenylalaninemia, whereas elevated levels can cause brain damage (Moore & Langley, 2008). Phenylalanine was lower than Aro and Aletor (2012).

Dietary fats consist of triglycerides (Mensink, 2016), while fatty acids (FA) vary by chain length and saturation (Astrup, 2019; Lund & Rustan, 2020). Polyunsaturated FAs influence health; Omega-3 is vital for fetal and brain development, while Omega-6 regulates the central nervous system and immune functions. These essential FAs must be obtained through the diet from sources such as fish or vegetable oils (Maurya et al., 2018). Omega-3 was only found in TMS 98/0505 (yellow), likely due to beta-carotenes.

Magnesium and calcium levels were higher than those recorded by Charles et al. (2005). Low values of sodium, phosphorus, zinc, and copper were consistent with those reported by Charles et al. (2005). TMS 98/0505 (yellow) had significantly higher sodium, potassium, calcium, and zinc, while ferric was higher in TME 419 and phosphorus in TMS 30572. Results were higher than Onigbinde (2001). The higher mineral content in the yellow variety may be due to beta-carotene, which is converted to vitamin A.

Conclusion

The study revealed significant varietal differences in the properties of various flours used, with potential for a wide range of end uses, particularly TMS 98/0505 (yellow), which has high ash, crude protein, fibre, and mineral content for both human food and animal feed. Vitamin A is an essential micronutrient for the normal functioning of the visual and immune systems, growth and development, maintenance of epithelial cell integrity, and reproduction in the TMS 98/0505 (yellow).

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