ISSN:
Print - 2277 - 0593
Online - 2315 - 7461

Journal of Natural Science, Engineering and Technology

PROXIMATE COMPOSITION, FUNCTIONAL AND COLOUR PROPERTIES OF EXTRUDED SNACKS FROM FERMENTED SORGHUM-PUMPKIN LEAF COMPOSITE FLOUR

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ABSTRACT

There is a need to further explore evolving technological processes and affordable nutrient sources to produce nutritionally adequate ready-to-eat products. This study was aimed at determining the effects of pumpkin leaf flour on the proximate composition, functional and colour properties of extruded snacks from fermented sorghum-pumpkin leaf flour. D-optimal mixture design was used to generate percentage of fermented sorghum and pumpkin leaf flour which resulted into ten experimental runs. The sorghum grains were fermented naturally for 24 h and were further processed into flour. Extruded snacks were produced from the ten runs and were analyzed for proximate composition, functional and colour properties using standard analytical procedures. Crude protein, crude fibre and total ash increased significantly ($p<0.05$) with increase in pumpkin leaf flour in the extruded snacks while water absorption index, bulk density, expansion ratio and lightness decrease significantly ($p<0.05$) with increase in pumpkin leaf flour. The optimum combination for extruded snacks were fermented sorghum flour of 86.24% and pumpkin leaf flour of 13.76%.

Keywords: Pumpkin leaf, Sorghum fermentation, Extrusion, Snacks

INTRODUCTION

Snacks contribute significantly to the nutrient intake of many children and adults. They are majorly prepared to be taken in-between meals. Snacks are gaining popularity due to their cost, accessibility and convenience (Marangoni *et al.,* 2019). Cereals are the major raw materials used in the preparation of snacks which may be due to their qualities, availability and cost (Dayakar *et al.,* 2018). Unexplored locally grown cereals can be processed commercially to create value-added food products, which drive economy in developing countries. Sorghum (*Sorghum bicolor*) is one of the most staple foods in the arid and remote sub-tropical regions of Africa. It is a superior source of protein and antioxidants (Dayakar *et al.*, 2018). Sorghum starch releases carbohydrate more gradually than other grains, which is advantageous in the management of diabetes or obesity (Wu *et al.,* 2017). Sorghum flour is gluten-free, making it an excellent alternative for those allergic to gluten.

Fermentation is an important process which lowers the content of anti-nutrients such as phytates, tannins, polyphenol of cereal grains (Sanlier *et al.,* 2019). A reduction in phytate may result in an increase of several folds in the amount of soluble iron, zinc, calcium and magnesium, which are found in cereals as complexes with polyvalent cations such as iron, zinc, calcium, magnesium (Yin *et al*. 2019).

Fluted pumpkin (*Telfairia occidentalis*) belongs to the genus Cucurbita and the family Cucurbitaceae, which includes a diverse range of plants with large leaves, creeping or climbing stems, usually with tendrils, and fleshy fruits with many seeds (Batool *et al*., 2022). It is a green leafy vegetable with high nutritional and therapeutic properties (Ndor *et al.,* 2013). The Igbo ethnic group of Nigeria refers to it as *Ugwu* and the word has become widely used in most parts of the country. Fluted pumpkin leaf contains anti-inflammatory, anti-cholesterolemic contents, and has the ability to improve haematological parameters (Obeagu *et al*., 2014).

In the food industry, extrusion is one of the most versatile operations for converting ingredients into intermediates and finished goods (Dayakar *et al*., 2018). Extrusion cooking is a process in which food materials are forced to flow under one or several conditions of mixing, heating and shear, through a cylindrical barrel in order to form and/or puff-dries the ingredients (Sobukola *et al.,* 2013). During extrusion cooking process, starchy foods result into gelatinization and degradation of starch, protein denaturation, modification of lipid, inactivation of enzymes and decreases microbial contamination and inactivate enzymes (Oke *et al.,* 2022). Different numbers of food products have been made by extrusion cooking including snacks, cereals, textured vegetable protein, confectioneries, and pet foods (Dayakar et al., 2018). The technology of extrusion cooking enables large-scale processing of raw ingredients at low cost. However, information is scanty on the performance of fermented sorghum and pumpkin leaf flour for the production of extruded snacks. Therefore, the objective of the study was to determine the proximate composition, functional and colour properties of extruded snacks from fermented sorghum-pumpkin leaf flour.

MATERIALS AND METHODS

Materials

Sorghum grains of white variety, fresh pumpkin leaves, milk powder, sugar and salt were obtained from Eleweran market, Abeokuta, Ogun state, Nigeria

Production of fermented sorghum flour

The fermented sorghum flour sample was prepared according to the method described by Ojo *et al.* (2023). The sorghum grains were carefully sorted to remove all unwanted materials. They were then rinsed with clean water, allowed to ferment for 24 h, and oven (GALLENKAMP SG3-08-169, UK) dried. The dried grains were milled into flour using a laboratory hammer mill (Fritsch, D-55743, Idar- oberstein-Germany), packaged in a polythene bag and stored at ambient temperature (26 ± 2 °C).

Preparation of pumpkin leaf flour

Pumpkin leaf flour was prepared according to the method described by Lawal *et al.* (2021). Pumpkin leaves were washed carefully with tap water to remove dirt and sorted to remove stalks. The green leaves were drained using a plastic sieve, then sliced and dried at 60°C for 5 h using oven dryer (GALLENKAMP SG3-08-169, UK). Dried pumpkin leaves were milled using laboratory electric blender (PANASONIC 2J MX-GX1001), cooled and stored at room temperature (27±2ºC) until needed.

Formulation of fermented sorghum-pumpkin leaf composite flour for extruded snacks

Fermented sorghum and pumpkin leaf flour were blended together with fermented sorghum flour using D-optimal mixture design and this resulted into ten experimental runs (Table 1).

Table 1: Formulation of fermented sorghum-pumpkin leaf composite flour for extruded snacks

Experimental Runs	Fermented Sorghum Flour (%)	Fluted Pumpkin Leaf Flour (%)
1	100	0.00
2	97.00	3.00
3	95.25	4.75
4	93.50	6.50
5	91.75	8.25
6	90.00	10.00
7	97.00	3.00
8	93.50	6.50
9	90.00	10.00
10	97.00	3.00

Production of extruded snacks from fermented sorghum-pumpkin leaf composite flour

The extruded snacks were produced according to the technique of Ojo *et al.* (2023). 100 g of extruded composite flour samples were added to other ingredients (7.5% sugar, 0.75% salt, 21% milk powder and 50 ml of hot water at 80-90 ºC) and it was left for 2 min for uniform hydration. A laboratory single screw extruder with screw length per diameter (16.43:1), screw diameter (18.5 mm) and length (304 mm) were used. Band heater was used to heat the barrel section. It was allowed to operate at full speed with a constant condition of barrel temperature (80 ºC), screw speed (60 rpm) and feed moisture of 27% (wet basis). Extruded snacks were cut into smaller pieces (2 cm length) and were allowed to dry in a hot air oven (Genlab, OV/ DIG, UK) at 60 ºC for 3 h to get the fermented sorghum-pumpkin leaf extruded snacks. The extruded snacks were cooled to ambient temperature (26 ± 2 °C), packaged in high density polyethylene bags and stored before usage.

Proximate composition of extruded snacks from fermented sorghum-pumpkin leaf composite flour

Moisture content, total ash, crude protein, crude fat, crude fibre contents were determined using the procedure of AOAC (2010). The total carbohydrate content was determined by difference.

Functional properties of extruded snacks from fermented sorghum-pumpkin leaf composite flour

Expansion ratio

The ratio of diameter of samples and the diameter of die was used to express the expansion of the extruded snacks (Fan *et al.,* 1996).

$$\text{Expansion ratio} = \frac{\text{Diameter of extrudates}}{\text{Diameter of die hole}}$$

Determination of bulk density

The bulk density of extruded snacks was measured following the method of Adeleke and Odedeji (2010). The volume of the expanded sample was measured by using a 100 ml. graduated cylinder by rapeseed displacement and gently tapped for 5 times. The volume of 20 g randomized samples was measured for each test. The ratio of sample weight and the replaced volume in the cylinder was calculated as bulk density (w/v).

$$\text{Bulk density } (g/ml) = \frac{\text{Weight of extrudates}}{\text{volume displaced by extrudates}}$$

Determination of water absorption index and water solubility index

Water absorption index and water solubility index were determined according to the method developed by Adeleke and Odedeji (2010). The ground extruded snacks were suspended in water at room temperature for 30 min, gently stirred during this period, and then centrifuged at 3000 g for 15 min. The supernatants were decanted into an evaporating dish of known weight. The water absorption index was the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. The water solubility index was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample.

$$\text{Water absorption index } (g/g) = \frac{\text{weight of sediment}}{\text{weight of dry solids}}$$

$$\text{Water solubility index } (\%) = \frac{\text{Weight of dissolved solid in supernatent}}{\text{weight of dry solids}} \times 100\%$$

Determination of colour properties

The approach outlined by Tugrul *et al.* (2018) was used. The colour of the samples were measured using a Minolta chroma meter (CR-410, Japan) based on the (CIE) L* a* b* scale. A white calibration plate and a zero-calibration mask were covered after the instrument had been calibrated. Extruded snacks were analyzed by putting them directly on the petri dish and the images were taken on the samples. Colour properties such as lightness, redness and yellowness were recorded.

Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) using SPSS 21.0. Mean separation was conducted using Duncan multiple range tests at $p < 0.05$. The effect of optimization procedure was checked using design expert base on D-optimal mixture design and significant effects of the independent variables were determined at 5% confidence level

Optimization process of extruded snacks from fermented sorghum-pumpkin leaf composite flour

Based on certain significant attributes associated with extruded snacks and desirability concept, Design Expert Version 12.0 was used to establish extruded snacks of acceptable properties. Crude protein content, crude fibre content and expansion ratio, lightness were maximized while moisture content, water absorption index and bulk density were minimized.

RESULTS

Proximate composition of the extruded snacks from fermented sorghum-pumpkin leaf composite flour

There were significant differences in all the proximate composition of extruded snacks (Table 2). The mean value of moisture content ranged from 6.29 - 9.01%. The interaction effects of extruded snacks from fermented sorghum and fluted pumpkin leaf flour had a significant effect on the moisture content (Table 3). The crude protein content ranged from 15.05 - 16.91%. The linear and interaction effect of fermented sorghum flour and pumpkin leaf flour had no significant effect on the crude protein. Crude fat content ranged from 3.26 - 4.67 % and crude fibre content ranged from 2.46 - 4.95%. The least value was found in 100% sorghum flour and the highest value was found in 90% fermented sorghum flour and 10% pumpkin leaf flour. The interaction effect of extruded snacks from fermented sorghum flour and pumpkin leaf flour had a significant effect on the fibre content with the coefficient of determination of 0.97 (Table 3). Crude fibre increased significantly with increased in pumpkin leave flour. The total ash content ranged from 4.77 - 8.24%. Total carbohydrate content ranged from 58.38 – 66.74%. The interaction effect of fermented sorghum and pumpkin leaf flour had a significant effect on the total carbohydrate of the extruded snacks (Table 3).

Functional properties of the extruded snacks from fermented sorghum-pumpkin leaf composite flour

Significant differences were observed in all the functional properties of the extruded snacks. The expansion ratio ranged from 6.20 – 8.35%, bulk density ranged from 0.36 - 0.74 g/ml. The lowest value was observed in 90% fermented sorghum flour and 10% pumpkin leaf flour. Water solubility index and water absorption index ranged from 2.10 – 4.70% and 3.48-4.19% respectively. The interaction effect of fermented sorghum and pumpkin leaf had a significant effect on the water solubility index of the extruded snacks (Table 5).

Table 2: Proximate composition of extruded snacks from fermented sorghum-pumpkin leaf composite flour

FS (%)	FP (%)	Moisture Content (%)	Crude Protein (%)	Crude Fat (%)	Crude Fibre (%)	Total Ash (%)	Total Carbohydrate (%)
100	0.00	9.01[e]	15.05[a]	4.61[c]	2.46[a]	4.77[a]	66.74[e]
97.00	3.00	7.95[d]	15.14[a]	4.51[c]	3.34[b]	5.78[a]	65.28[d]
95.25	4.75	7.30[c]	15.53[a]	4.37[c]	3.47[b]	5.80[b]	65.53[d]
93.50	6.50	7.09[c]	16.54[b]	3.87[b]	3.59[b]	6.19[cd]	64.22[cd]
91.75	8.25	6.99[b]	16.74[b]	3.57[a]	4.34[cd]	6.79[e]	61.37[b]
90.00	10.00	6.29[a]	16.82[b]	3.26[a]	4.92[d]	8.21[f]	59.43[a]
97.00	3.00	7.98[d]	15.17[a]	4.54[c]	3.37[b]	5.79[a]	65.15[d]
93.50	6.50	7.12[c]	16.47[a]	3.90[b]	3.42[bc]	6.23[cd]	63.06[c]
90.00	10.00	6.32[a]	16.91[b]	3.39[a]	4.95[cd]	8.24[f]	58.38[a]
97.00	3.00	7.51[cd]	15.20[a]	4.57[c]	3.40[b]	5.72[a]	65.60[c]

Mean values with different superscripts within the same column are significantly different ($p < 0.05$); FS- Fermented Sorghum flour, FP- Fluted Pumpkin flour

Table 3: Regression coefficient of proximate composition of extruded snacks from fermented sorghum-pumpkin leaf composite flour

Parameter	Moisture Content	Crude Protein	Crude Fat	Crude Fibre	Total Ash	Total Carbohydrate
A	15.73	8.25	0.60	2.37	1.80	61.13
B	15.17	8.48	1.42	1.95	1.30	61.73
AB	6.53*	1.02	-0.021	1.11*	0.40	-5.71*
F-value	11.90	0.53	9.31	87.47	3.06	3.11
R^2	0.7987	0.1490	0.7563	0.9668	0.5050	0.6088

*Significant at $p<0.05$: A- fermented sorghum flour, B-Fluted pumpkin leaf flour, AB- Interaction effects of fermented sorghum and Fluted pumpkin leaf flour, R^2- Coefficient of determination

Table 4: Functional properties of extruded snacks from fermented sorghum-pumpkin leaf composite flour

FS (%)	FP (%)	Expansion Ratio (%)	Bulk Density (g/ml)	Water Solubility Index (%)	Water Absorption Index (%)
100	0.00	8.35^{e}	0.74^{b}	4.70^{f}	4.91^{c}
97.00	3.00	7.61^{cd}	0.72^{e}	3.79^{e}	3.96^{ab}
95.25	4.75	7.51^{c}	0.66^{c}	3.74^{cd}	3.95^{ab}
93.50	6.50	7.44^{c}	0.50^{g}	3.34^{c}	3.95^{ab}
91.75	8.25	6.47^{ab}	0.46^{a}	2.90^{b}	3.64^{a}
90.00	10.00	6.20^{a}	0.36^{d}	2.10^{a}	3.55^{a}
97.00	3.00	7.51^{cd}	0.78^{ef}	3.62^{ab}	3.94^{ab}
93.50	6.50	7.2^{c}	0.40^{g}	3.37^{c}	3.92^{ab}
90.00	10.00	6.54^{b}	0.36^{d}	2.13^{a}	3.48^{a}
97.00	3.00	7.58^{d}	0.69^{f}	2.46^{ab}	3.87^{b}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$); FS- Fermented Sorghum flour, FP-Fluted Pumpkin flour

Table 5: Regression coefficient of functional properties of extruded snacks from fermented sorghum-pumpkin leaf composite flour

Parameter	Expansion Ratio	Bulk Density	Water Solubility Index	Water Absorption Index
A	1.54	0.38	2.48	4.59
B	1.52	0.35	2.00	4.99
AB	-0.079	0.035	7.49*	-1.10
F-value	0.53	0.78	34.1	0.59
R^2	0.1494	0.2059	0.9193	0.1643

*Significant at $p<0.05$: A- Fermented sorghum flour, B- Pumpkin leaf flour, AB- Interaction effects of fermented sorghum and Fluted pumpkin leaf flour, R^2- Coefficient of determination

Colour properties of the extruded snacks from fermented sorghum-pumpkin leaf composite flour

The mean value of lightness (L*) ranged from 12.81 - 27.84 (Table 6). The linear relationship of pumpkin leaf flour had a significant effect on the lightness of the extruded snacks (Table 7). The highest value was found in 100% extruded snacks produced from sorghum flour and the least value was found in extruded snacks produced from 90% fermented sorghum flour and 10% pumpkin leaf flour. The redness (a*) and yellowness values ranged from 1.03 - 4.92 and 5.89-11.50 respectively.

Solution to process optimization of extruded snacks from fermented sorghum-pumpkin leaf composite flour

Based on certain significant desirable attributes associated with extruded snacks which include high crude protein content, crude fibre content, expansion ratio, lightness and low moisture content, water absorption index and bulk density. Crude protein content (24.45), crude fibre content (3.99), expansion ratio (9.47) and lightness (26.44), were maximized while moisture content (6.42), water absorption index (3.08) and bulk density (0.50) were minimized to obtain an optimum combination (fermented sorghum flour of 91.02% and pumpkin leaf flour of 8.98%) and a desirability of 0.87 (Table 8).

Table 6: Colour properties of extruded snacks from fermented sorghum-pumpkin leaf composite flour

FS (%)	FP (%)	Lightness (L*)	Redness (a*)	Yellowness (b*)
100	0	27.84^{d}	4.92^{f}	5.89^{f}
97.00	3.00	24.52^{a}	3.01^{e}	6.79^{a}
95.25	4.75	21.89^{c}	2.14^{cd}	7.46^{e}
93.50	6.50	20.37^{c}	1.92^{c}	7.79^{b}
91.75	8.25	17.86^{b}	1.58^{ab}	9.12^{d}
90.00	10.00	12.81^{b}	1.10^{a}	11.47^{c}
97.00	3.00	15.75^{a}	3.11^{e}	6.70^{a}
93.50	6.50	20.40^{c}	1.85^{c}	7.82^{b}
90.00	10.00	17.97^{b}	1.03^{a}	11.50^{c}
97.00	3.00	15.91^{a}	3.14^{e}	6.73^{a}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$); FS- Fermented Sorghum flour, FP- Fluted Pumpkin leaf flour

Table 7: Regression coefficient of colour properties of extruded snacks from fermented sorghum-pumpkin leaf composite flour

Parameter	Lightness	Redness	Yellowness
A	15.93	3.09	6.00
B	17.49*	1.45	8.48
AB	13.56	-4.46	2.83
F-value	15.60*	16.23	3.40
R^2	0.8387	0.8440	0.5314

*Significant at $p<0.05$: A- Fermented sorghum flour, B- Pumpkin leaf flour, AB- Interaction effects of fermented sorghum and fluted pumpkin leaf flour, R^2- Coefficient of determination

Table 8: Solution to process optimization of extruded snacks from fermented sorghum-pumpkin leaf composite flour

FSF (%)	FPLF (%)	Crude protein (%)	Crude fibre (%)	MC (%)	Expansion ratio (%)	Bulk density (%)	WAI (%)	Lightness (L*)	Desirability
86.24	13.76	24.45	3.99	6.42	9.47	0.50	3.08	26.44	0.87

FSF- Fermented sorghum flour FPLF- FIuted Pumpkin leaf flour, MC- Moisture content, ER Expansion ratio, WAI – Water absorption index

DISCUSSION

The moisture content is a measure of the water content available in food and also an indication of the dry matter in that food (Adegunwa *et al.,* 2014). Therefore, the low moisture content of all the extruded snacks were within 10% limit stated by World Food Programme (WFP) thus makes it less liable to microbial attack and would have longer shelf stability. Various researchers such as Azeez *et al.* (2015) and Oke *et al.* (2022) also reported a lower value in the moisture content of extruded products. The result obtained in this study is lower than the range of value of 15.13 - 16.43 % reported by Olunlade *et al.* (2013) for extruded products from corn, millet and soybean blend. The crude fat content decreased significantly with increase in pumpkin leaf powder. However, crude fat contents of these extruded snacks were close to the range of 2.32 - 4.58 % reported by Semasaka *et al.* (2010) for extruded products from corn, millet and soybean blend. However, Kaur *et al.* (2018) reported that extrusion cooking assist oil extraction since oil is free during cooking and shearing operations which break fat globules. The reduced fat content as pumpkin leaf flour increased will decrease the chance of rancidity in the extruded snacks and also contribute to low energy of the extruded snacks. Fat plays a significant part in the shelf stability of food products, and this is because fat support rancidity in foods, thereby leading to increase in unpleasant and odorous compounds (Oke *et al.*, 2022).

The increase in crude fibre content as pumpkin leaf flour increases suggest that extruded snacks made from fermented sorghum and pumpkin leaf composite flour will play a crucial part in maintaining intestinal health, lowering glucose levels, aid digestion and promote bowel movement (Kaur *et al.*, 2018). The total ash content increased as the pumpkin leaf flour increased, this could suggest that extruded snacks from fermented sorghum and pumpkin leaf flour will be a good source of mineral elements (Kaur *et al.*, 2018). It was observed that the total carbohydrate content of the extruded snacks decreased with increase in substitution of pumpkin leaf flour, this implies that pumpkin seed is not a good source of carbohydrate (Konadu *et al.*, 2021).

Expansion ratio is an important index of extruded snacks; it is used in describing the extent of puffing of snacks as it exits the die of the extruder (Sobukola *et al.,* 2013). Expansion ratio decreased significantly with increase in pumpkin leaf flour, this could be as a result of substitution of fermented sorghum flour with pumpkin leaf. However, Ogunmuyiwa *et al.* (2017) reported that fibre could be responsible for rupturing the walls of air cells as well as the external surface of the extrudates, thereby preventing full expansion of the gas bubbles. Several researchers such as Kaur *et al.* (2018) and Oke *et al.* (2022) also reported decrease in the expansion ratio in extruded product. However, expansion taking place in food ingredients depends on the pressure differential between the die and atmosphere (Azeez *et al.,* 2015). Bulk density is one of the most important indices of quality of extruded food products. Bulk density of extruded products has been reported as one of the most important indices of quality in expanded food products (Oluwole *et al.*, 2013). Bulk density decreases significantly with increase in pumpkin leaf flour, which could be due to higher weight of sorghum compared to pumpkin leaf flour (Bello and Udo, 2018). This suggests that extruded snacks from fermented sorghum flour and pumpkin leaf flour will reduce shipping and packaging costs. The result obtained in this study is similar to the observation reported by Thymi *et al.* (2005), Deshpande and Poshadri, (2011) and Oluwole *et al.* (2013) on low bulk density values of extruded snacks.

The water solubility index (WSI) determines the quantity of soluble polysaccharide released from the starch granules after adding up excess water and is often used as an indicator of degradation of molecular components which is related to dextrinization (Marangoni *et al.,* 2019). Water solubility decreases significantly with increase in pumpkin leaf flour this could have been due to degradation of starch which could have reduce the extruded snacks from extent of gelatinization (Kisambari *et al.,* 2015). The water absorption index (WAI) give insight to the extent of gelatinization of starch in the feed ingredient generally by measuring the amount of water absorbed by starch granules after swelling in excess of water originally present in the product (Kisambari *et al.,* 2015). WAI depends on the availability of hydrophilic groups which bind water molecules and the gel-forming capacity of the macromolecules involved. Water absorption index of the extruded snacks decreased significantly as the substitution of pumpkin leaf flour increases. This might be due to relative decrease in starch content with addition of pumpkin leaf flour; this will promote increased hardness and reduced expansion in the final products (Gandhi and Singh, 2015).

Colour is an important aspect of quality since it has a direct impact on consumers' propensity to buy (Sara and Ayat, 2022). Increase in pumpkin leaf flour reduces the lightness of the extruded snacks thereby resulting in low value for lightness. Increase in pumpkin leaf flour increased the yellowness, decreases the redness to a low value that is tending to negative which could be as a result of the green pigment in pumpkin leaves as negative value for redness is greenness (Saidi *et al.,* 2023).

CONCLUSION

The study demonstrated that incorporation of pumpkin leaf flour to fermented sorghum flour in the production of extruded snacks had a significant effect on the proximate composition, functional and colour properties. Based on the outcome of the optimization process, the optimum combination for extruded snacks were fermented sorghum flour of 86.24% and pumpkin leaf flour of 13.76%. However, further studies should be carried out on the shelf-life of extruded snacks from fermented sorghum-pumpkin leaf blends.

REFERENCES

Adegunwa, M. O., Ganiyu, A. A., Bakare H. A., Adebowale, A. A. 2014. Quality evaluation of composite millet-wheat chin-chin. *Agriculture and Biology Journal of North America.* 5(1): 33 -39.

Adeleke, O. R., Odedeji, O. J. 2010. Functional properties of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition* 9(6): 535-538.

A.O.A.C. 2010. Official Methods of Analysis, 18th ed. Association of Official Analytical Chemists, Washington, D. C., USA.

Azeez, A. T., Adegunwa, M. O., Sobukola, O. P., Onabanjo, O. O., Adebowale, A. A. 2015. Evaluation of some quality attributes of noodles from unripe plantain and defatted sesame flour blends. *Journal of Culinary Science and Technology.* 13:4, 303-329.

Batool, M., Ranjha, M., Roobab, U., Manzoor, M. F., Farooq, U., Nadeem, H. R. 2022. Nutritional value, phytochemical potential, and therapeutic benefits of pumpkin (Cucurbita sp.). *Plants* 11: 13-20.

Bello, F., Udo, J. 2018. Effect of processing methods on the nutritional composition and functional properties of flours from white and yellow local maize varieties. *Journal of Advanced in Food Science and Technology.* 5: 1-7.

Dayakar, B. R., Suneetha, A., Kiranmai, E., Srenuja, D., Tonapi, V. A. 2018. Development of multi millet based extruded snack food. *International Journal of Chemical Studies.* 6(4): 1748-1752.

Deshpande, H.W., Poshadri, A. (2011). Physical and sensory characteristics of extruded snacks prepared from foxtail millet based composite flours. *International Food Research Journal.* 18: 751- 756.

Fan, J., Mitchell, R. J., Blanchard, V. M. 1996. The Effect of sugars on the extrusion of maize grits: The role of the glass transition in determining product density and shape. *International Journal of Food Science and Technology.* 31: 55–65.

Gandhi, N., Singh, B. 2015. Study of extrusion behaviour and porridge making characteristics of wheat and guava blends. *Journal of Food Science and Technology.* 52 (5): 3030-3036.

Kaur, G., Singh, B., Javed, M. (2018). Nutritional evaluation of cereal-pulse based extruded snacks supplemented with dehydrated herbs. *Current Journal of Applied Science and Technology.* 28(1): 1-14.

Kisambari, A, Muyonga J. H., Byaruhanga, Y. B., Tukamubabwa, P., Tumwegamiro, S., Gruneberg, W. (2015). Composition and functional properties of yam bean seed flour. *Food Nutrition Science.* 6: 736-746.

Konadu, M., Enoch, A., Quansah, P. A. 2021. Evaluation of proximate composition and selected physico-chemical properties of butternut squash. *International Journal of Food Sciences.* 4(1): 1-15.

Lawal, O. M., Sanni, O., Oluwamukomi, M., Fogliano, V., Linnemann, A. R. (2021). The addition of fluted pumpkin (Telfairia occidentalis) leaf powder improves the techno-functional properties of cassava pasta. *Food Structure.* 30: 241-250.

Marangoni, F., Martini, D., Scaglioni, S., Sculati, M., Donini, L. M., Leonardi, F., 2019. Snacking in nutrition and health. *International Journal of Food Sciences and Nutrition.* 70(8): 909-923.

Ndor, E., Dauda, S.N., Garba, M. N. 2013. growth and yield performances of fluted pumpkin (*telfairia occidentalis hook f.*) under organic and inorganic fertilizer on ultisols of north central Nigeria. *International Journal of Plant and Soil Science* 2: 212-221.

Obeagu, E. I., Chikelu, I. M., Obarezi, T. N., Ogbuabor, B.N. Anaebo, Q. B. 2014. Haematological effects of fluted pumpkin (Telfairia occidentalis) leaves in rats. *International Journal of Life Sciences Biotechnology and Pharma Research* 3(1): 172–182.

Ogunmuyiwa, O. H., Adebowale, A. A., Sobukola, O. P., Onabanjo, O. O., Obadina, A. O., Adegunwa, M. O., Kajihausa, O. E. 2017. Production and quality evaluation of extruded snacks from blends of bambara groundnut flour, cassava starch and corn bran flour. *Journal of Food Processing and Preservation.* 2016: 1-7.

Oluwole, O. B., Olapade, A. A., Awonorin, S. O., Henshaw, F. O. 2013. Physicochemical properties of extrudates from white yam and bambara nut blends. *International Agrophysics.* 27: 69-74.

Ojo, O. A., Oshin, A., Obadina, A. O., Oke, E. K. 2023. Mineral and antinutritional properties of pearl millet and pumpkin leaf flour as affected by fermentation. *Acta Univ. Sapientiae Alimentaria.* 16: 75-89.

Oke, E.K., Idowu, M.A., Okanlawon, K.O., Adeola, A.A., Olorode, O.O. 2022. Proximate composition, cooking and sensory properties of noodles from wheat-tigernut pomace flour blends at optimized condition using response surface methodology. *Journal of Culinary Science and Technology.* 22(3):547 – 573.

Olunlade, B, Adeola, A. A. Anuoluwapo, A. O. 2013. Microbial profile of maize-pigeon pea biscuit in storage. *Fountain Journal of Natural and Applied Sciences* 2(2): 1-9.

Tugrul, M, M., 2018. Physical properties of puffed yellow pea-snacks produced by nitrogen gas assisted extrusion cooking. *LWT Food Science and Technology* 93: 529-598.

Saidi, I. A., Azara, R., Efendi, N., Kartika, S. D. 2023. Physicochemical characteristics of home-made ice cream with mustard green (*Brassica juncea*) powder or puree. *African Journal of Food and Agriculture Development.* 23(9): 24680-24695.

Sanlier, N., Gokcen, B. B., Sezgin, A. C. 2019. Health benefits of fermented foods. Critical Review. Food Science and Nutrition. 59: 506–527.

Sara, A. A., Ayat, E. R. 2022. Production and e valuation of novel functional extruded corn snacks fortified with ginger, bay leaves and turmeric powder. *Food Production, Processing and Nutrition.* 4(4): 1-17.

Semasaka, C, Kong, X. Hua, Y. 2010. Optimization of extrusion on blend flour composed of corn, millet and soybean. *Pakistan Journal of Nutrition* 9(3): 291-297.

Sobukola, O.P., Dueik, V., Bouchon, P. 2013. Understanding the effect of vacuum level in structure development and oil absorption in vacuum-fried wheat starch and gluten-based snacks. *Food and Bioprocess Technology*. 6(8): 2010-2017.

Thymi, S., Krokida, M. K., Pappa, A. and Maroulis, Z. B. 2005. Structural properties of extruded corn starch. *Journal of Food Eng*ineering. 1: 519-526.

Wu, G., Bennett, S. J., Bornman, J. F., Clarke, M. W., Fang, Z., Johnson, S. K. 2017. Phenolic profile and content of sorghum grains under different irrigation managements. *Food Resources International*. 97: 347-355.

Yin, Z. N., Wu, W. J., Sun, C. Z., Liu, H. F., Chen, W. B., Zhan, Q. P., Lei, Z. G., Xin, X., Ma, J. J., Yao, K. 2019. Antioxidant and anti-inflammatory capacity of ferulic acid released from wheat bran by solid-state fermentation of *aspergillus niger*. *Biomedicine Environmental Science*. 32: 11–21.

(Manuscript received: 9th December, 2024; accepted: 26th May, 2025).