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Research Article

Principal component analysis of cake's physical, proximate and sensory attributes as influenced by wheat, malted and nixtamalized maize flour blends

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Abstract: Wheat remains the primary ingredient in cake production; however, consumers increasingly seek affordable, gluten-free alternatives. Malting and nixtamalization are processing methods that significantly enhance nutritional and functional properties of cereals. This study utilised Principal Component Analysis (PCA) to analyse the influence of maize malting and nixtamalization. Cake samples were produced from wheat, malted maize, and nixtamalized maize flour blends. Physical and proximate properties were determined using standard methods, and sensory attributes were assessed on a 9-point hedonic scale. The physical properties and proximate compositions of the cake samples were weight (43.65–45.67 g), height (3.22–4.22 cm), volume (405.86–690.05 cm^3); and moisture (12.77–16.80%), fat (22.81–31.57%), protein (6.31–14.14%), crude fibre (0.25–0.86%), ash (0.76–1.12%), carbohydrate (36.91–52.58%) and energy (450.12–488.52 kcal) respectively. Sensory profiles of cakes with up to 50% nixtamalized maize did not differ significantly from the 100% wheat control. The PCA correlation loading established that 100% wheat and 50% nixtamalized maize composite cakes correlated positively with all sensory parameters. The PCA biplot placed malted maize-wheat composite cakes in the same quadrant as protein and ash content. Malted and nixtamalized maize flours produced cakes with improved nutrition without compromising physical or sensory quality.

Keywords: Cake, Malting, Germination, PCA, Maize

1. Introduction

Wheat flour remains the predominant raw material for the formulation of bakery products. However, the absence of cost-effective alternatives to wheat is a major cause of the continuous rise in the cost of bakery products in non-wheat-producing nations (Grote et al., 2021). This has necessitated research efforts (Osunrinade et al., 2025) that sought to provide alternatives in terms of composite formulations that utilise locally available crops for partial or full substitution of wheat flour.

Generally, composite flours are often composed of variations of starchy or protein-rich flours from cereals, legumes or other sources with or without wheat flour. The technology of composite flours is critical for the management of costs associated with the use of wheat flour in nations where climatic conditions are not suitable for wheat production (Grote et al., 2021). Reports indicated that the use of non-wheat flour for bakery products could result in huge savings and enhancement of food security in non-wheat-producing nations (Amena et al., 2024). Considering the societal changing lifestyle, there is a rise in the consumption of baked food products, with cake as a leading example (Xu et al., 2020). The importance of composite flour research is further explained by the ever-increasing urban populations (Obayelu, 2019). The substitution of wheat

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with composite flours could ensure that consumers have access to cake with nutrient-dense properties.

Cereals are generally limited in some essential nutrients that are important in human daily activities. Sometimes, when the nutrients are present in cereals, they are not available for the body to metabolise. Cereal processing often increases nutrient availability, sensory acceptability and improvement in the technological properties of the final product (Avelar et al., 2024). The need for cereal pretreatment such as fermentation, germination and nixtamalization, among many others, is inevitable due to their potential to increase the availability of nutrients and transform available components to a more needed nutrient through various chemical reactions. Pre-treated cereals have gained wide application in the production of intermediate raw materials like flours used for bakery and confectionery (Adebo et al., 2022).

The nutritional values and palatability of cereals have been enhanced by different processing techniques. These techniques alleviate micronutrient deficiencies, particularly through the breakdown of certain antinutrients such as phytate and protease inhibitors (Adebo et al., 2022). Malting and nixtamalization are cereal processing methods that have been reported to impart significant changes to the functional and nutritive properties of cereals. Specifically, malting promotes changes in the biochemical, sensorial and nutritional properties of cereals (Rahman et al., 2023) while during nixtamalization done by cooking cereals in alkaline solution can improve the nutritional value of corn by increasing and providing lysine in the glutelin fraction as well as making the starch to be partially gelatinized and thus produces very important changes on thermal, structural, and rheological properties (Gaytán-Martínez et al., 2017).

The potential of maize *(Zea mays)* flour as a substitute for wheat in baked products can be enhanced through malting and nixtamalization, processes that improve its functional and nutritional properties. A previous study by Olaoye et al. (2015) established that incorporating malted maize flour into wheat-based cakes at levels up to 20% improves nutritional quality and reduces anti-nutritional factors. Hence, increasing the percentage incorporation of maize flour by maize pretreatment (malting and nixtamalizing) could help drive down the cost of cake (Sanodiya et al., 2024), enhance affordability for low-income populations and improve the nutritive value of baked products. Researchers have used maize as a substitute for wheat in the production of cake (Ogunbusola et al., 2021; Xu et al., 2020); however, there is a dearth of knowledge on the use of composite flour from malted and nixtamalized maize to produce cake. This study utilised Principal Component Analysis (PCA) to analyse the influence of maize malting and nixtamalization on the cake's physical, proximate and sensory attributes.

2. Materials and Methods

2.1. Materials

The raw materials used in this work are yellow maize grain, commercially available refined wheat flour, sugar, margarine, milk flavour, and egg, which were obtained from Sango market, Saki, Oyo state, Nigeria. Equipment and utensils used were blender, mixing machine, baking pan, weighing scale, bowl, receiving table dough, and baking oven.

2.2. Production of nixtamalized maize flour

Maize was nixtamalized using the method described by Ogunbusola et al. (2021) with slight modifications. Analytical grade Calcium hydroxide (20 g) was dissolved in 4,000 ml of clean water, followed by the steeping of 1 Kg of maize before being allowed to boil for 30

Table 1: Composite flour formulation for cake production

S/N	Sample code	Wheat (%)	Nixtamalized maize (%)	Germinated maize (%)
1	CWC	100	0	0
2	CMN	50	50	0
3	CMG	50	0	50
4	CWN	75	25	0
5	CWG	75	0	25
6	CNW	0	100	0
7	CGW	0	0	100

minutes. The cooked maize was passed through a sieve to remove the water before drying at 50 °C for 6 hours. The dried maize was milled into flour, cooled and sieved with a mesh size of 80 µm. The nixtamalized maize flour was packaged in a Ziploc bag before being placed in an airtight plastic container at ambient temperature until needed for analysis.

2.3. *Production of malted maize flour*

Maize grains were initially cleaned to eliminate impurities and foreign particles, followed by thorough rinsing in potable water. The cleaned grains were soaked in water for 1 hour and then drained. Subsequently, they were spread on moistened jute sacks and allowed to germinate under ambient conditions for 5 days. After germination, the grains were dried using a hot air oven (Gallenkamp, USA) at 65 °C for 6 hours. Once dried, the rootlets and shoots were separated from the grains through winnowing. They were then milled using a locally fabricated attrition mill, cooled and sieved to obtain malted maize flour that passed through an 80 µm sieve. The malted maize flour sample was packaged in a Ziploc bag kept in an airtight plastic container, stored at room temperature until use.

2.4. *Production of cake*

The method described by Osunrinade et al. (2020) was used for the production of queen's cake samples from the composite flour formulation presented in Table 1. Briefly, a mixture of 200 g sugar and baking fat (80 g) was mixed for 30 minutes until the grains of sugar disappear and the mixture becomes fluffy. Whipping of 4 eggs (160 g) was done with the mixture for about 5 minutes before the addition and sequential mixing of composite flour (500 g), baking powder (4 g) and a teaspoon of vanilla flavour. The final mix was poured into baking pans, and samples were baked at 180 °C for 15 minutes.

2.5. *Methods of cake analysis*

2.5.1. *Determination of physical properties of cake*

The physical properties determined for the cake samples included lower diameter, upper diameter, weight, height and volume. The method described by Osunrinade et al. (2020) was adopted. Specifically, the lower, higher diameter and height of cake samples were determined with a meter rule in centimetres, while the weighing scale with a precision of ±0.05 was used to establish the weight of cake samples in grams. The average of five cake samples was taken as a single measurement and done in triplicate. Presented in equation 1 is the formula used to determine the cake's volume in cm^3.

$$Cake's\ volume = \pi h(d^2 + db + b^2) \qquad equation\ 1$$

Where b represents the cake's lower diameter, d represents the cake's upper diameter, h represents the cake's height, and $\pi = \frac{22}{7}$

2.5.2. *Determination of proximate composition and energy of cake*

The moisture, ash, crude fibre, protein, fat and carbohydrate contents of cake samples were determined using AOAC (2005) methods. Briefly, the oven method with a 2 g cake sample placed in a forced draught oven operated at 105 °C for 6 hours was used to determine the moisture content of cake samples. The ash content was determined by placing 3 g of cake samples in an empty porcelain crucible placed in a muffle furnace preheated and operated at 550 °C for 2 hours. The Kjeldahl method, which involves the digestion of 1 g sample with Kjeldahl catalyst, followed by distillation, while the titration result was used to estimate the protein content of cake samples. The crude fibre of cake samples was determined by hydrolysis of 2 g of cake samples in an acid and then an alkaline solution through boiling under reflux. Soxhlet apparatus using hexane as solvent was used to determine the fat content of cake samples, while the carbohydrate content of cake samples was estimated by subtracting the addition of moisture, ash, crude fibre, protein and fat from 100. Also, the energy value was calculated using the ATWATER factor of 4 Kcal for protein, 4 Kcal for carbohydrate and 8 Kcal for fat.

2.5.3. *Sensory evaluation of cake*

A consumer-oriented affective test was employed to evaluate the palatability of the composite cakes. Sensory acceptability of the cake samples was determined by a semi-trained panel of thirty students, selected based on their status as regular cake consumers. Evaluation was conducted in a controlled sensory laboratory under white fluorescent lighting to ensure accurate colour perception. To prevent bias, samples were presented in a randomised order and served at room temperature on neutral white plates, coded with three-digit random numbers. Between samples, panellists were provided with room-temperature water as a palate cleanser to prevent cross-contamination of flavours. Panellists were instructed to evaluate the cakes for six quality characteristics: Appearance, aroma, taste, texture, fluffiness, and overall acceptability. Each attribute was rated using a 9-point Hedonic scale, where 1 represented "disliked extremely" and 9 represented "liked extremely".

2.5.4. Statistical analysis

Statistical analysis was conducted using SPSS (Statistical Program for Social Sciences) version 21.0 for Windows. The analysis of variance was carried out by the separation of means from triplicate observations at 5% level of significance using the Duncan multiple range test.

3. Results and discussion

3.1. Physical properties of cake

The upper diameter (4.62–5.86 cm), lower diameter (2.09–2.88 cm), weight (43.65–45.67 g), height (3.22–4.22 cm), and volume (405.86–690.05 cm^3) of the cake samples are shown in Table 2. There was significant variation at $p<0.05$ in cake samples' physical properties. The control sample made from 100% wheat flour had significantly higher physical properties compared to other samples. Comparatively higher physical properties in the cake sample from wheat flour are attributable to the gluten's viscoelasticity, which promotes air entrapment and structural stability during baking (Conte et al., 2016). Cake samples made from composite (50% malted maize and 50% wheat) were the closest to the control in terms of all physical properties of cake samples.

Comparing nixtamalized and malted maize for cake production, 100% malted maize cake had significantly higher physical properties in terms of diameter, weight, height and volume than the 100% nixtamalized maize cake sample. Cake samples from composites (malted maize and wheat flour) had higher and more desirable physical properties that are comparable to the control (wheat flour) cake sample. This is likely due to the synergistic effects of the residual gluten in wheat flour and the improved functional properties of malted maize. Malted grains undergo enzymatic modifications during germination, resulting in partial hydrolysis of starch and proteins, which can enhance water absorption, batter viscosity, and gas retention capacity during baking (Rahman et al., 2023). These factors contribute to better aeration, increased expansion, and softer crumb in the final baked product. Moreover, malted maize flour tends to have reduced anti-nutritional factors and improved solubility and emulsification properties (Chaudhary et al., 2013), which enhance structural stability during baking. When blended with wheat flour, these improvements help compensate for reduced gluten content and support desirable cake texture and volume formation similar to conventional wheat-based cakes. The higher height and volume in the present study suggest that malted maize flour positively influenced batter aeration and expansion, potentially due to improved enzyme activity and starch modification during germination (Ohanenye et al., 2020).

The physical characteristics of the cake samples analysed in this study showed upper diameters ranging from 4.62 to 5.86 cm and lower diameters from 2.09 to 2.88 cm. These measurements are comparable to those reported by Okoye et al. (2017), who recorded upper diameters between 4.5 and 6.0 cm and lower diameters between 2.0 and 3.0 cm for cakes formulated with composite flours. The weight of the cakes in this study (43.65–45.67 g) aligns closely with the findings of Ayo

Table 2: Physical properties of cake samples

Samples	Upper diameter (cm)	Lower diameter (cm)	Weight (g)	Height (cm)	Volume (cm^3)
CWC	5.88 ± 0.12^{a}	2.17 ± 0.11^{cd}	43.65 ± 0.06^{b}	4.22 ± 0.02^{a}	690.05 ± 3.56^{a}
CMN	4.98 ± 0.12^{c}	2.09 ± 0.01^{d}	44.32 ± 0.01^{ab}	3.58 ± 0.02^{b}	445.17 ± 1.78^{e}
CMG	5.33 ± 0.03^{b}	2.84 ± 0.00^{a}	45.02 ± 0.00^{a}	3.38 ± 0.02^{c}	548.11 ± 3.28^{b}
CWN	4.84 ± 0.06^{d}	2.88 ± 0.00^{a}	45.37 ± 0.03^{a}	3.15 ± 0.01^{d}	451.93 ± 2.19^{d}
CWG	4.71 ± 0.09^{e}	2.30 ± 0.00^{b}	44.11 ± 0.01^{ab}	3.42 ± 0.04^{c}	411.63 ± 1.28^{f}
CNW	4.62 ± 0.02^{f}	2.6 ± 0.01^{c}	44.24 ± 0.00^{ab}	3.22 ± 0.06^{d}	405.86 ± 1.25^{g}
CGW	5.03 ± 0.01^{c}	2.88 ± 0.00^{a}	45.29 ± 0.00^{a}	3.04 ± 0.02^{e}	459.26 ± 2.17^{c}

Means with the same superscript within a column are not significantly different ($p < 0.05$).
CWC 100% wheat flour (control); CMN- 50% nixtamalized maize, 50% wheat; CMG - 50% malted maize flour, 50% wheat flour; CWN-75% nixtamalised maize, 25% wheat; CWG-75% malted maize flour, 25% wheat flour; CNW- 100% nixtamalization maize flour; CGW-100% malted maize flour

Table 3: Proximate and energy composition of cake samples

Sample	Moisture (%)	Fat (%)	Protein (%)	Fibre (%)	Ash (%)	Carbohydrate (%)	Energy (Kcal)
CWC	14.98±0.26[c]	30.31±0.26[a]	6.31±0.71[f]	0.35±0.04[d]	0.76±0.02[c]	47.32±0.76[b]	476.12±1.68[b]
CMN	13.57±0.25[e]	25.47±0.56[b]	8.67±0.26[e]	0.25±0.04[e]	0.95±0.02[abc]	51.31±0.07[a]	461.29±3.38[d]
CMG	14.42±0.03[d]	33.52±0.73[a]	11.27±0.06[c]	0.66±0.02[c]	1.12±0.02[a]	39.02±0.65[c]	488.52±3.19[a]
CWN	16.35±0.11[b]	31.26±0.56[a]	8.27±0.45[e]	0.35±0.02[d]	0.90±0.01[bc]	38.99±0.48[c]	471.85±1.25[bc]
CWG	13.32±0.09[e]	24.81±0.75[b]	12.18±0.39[b]	0.73±0.01[b]	0.95±0.01[abc]	51.27±0.57[a]	456.62±2.15[d]
CNW	12.77±0.26[f]	22.98±0.13[b]	9.81±0.40[d]	0.86±0.04[a]	1.01±0.03[ab]	52.58±0.08[a]	450.12±0.09[e]
CGW	16.80±0.07[a]	31.57±0.26[a]	14.14±0.13[a]	0.35±0.02[d]	0.95±0.01[abc]	36.21±0.34[c]	470.43±1.19[c]

Means with the same superscript within a column are not significantly different ($p < 0.05$).
CWC 100% wheat flour (control); CMN- 50% nixtamalized maize, 50% wheat; CMG - 50% malted maize flour, 50% wheat flour; CWN-75% nixtamalised maize, 25% wheat; CWG-75% malted maize flour, 25% wheat flour; CNW- 100% nixtamalization maize flour; CGW-100% malted maize flour

et al. (2018), who reported cake weights of 42.8–46.5 g, indicating consistency in formulation and portioning. Cake heights ranged from 3.22 to 4.22 cm, similar to the range (3.0–4.5 cm) observed by Igbabul & Amove (2016) in their work on cakes produced with plantain and wheat flour blends. The volume of the cakes, ranging from 405.86 to 690.05 cm³, is within the range reported by Oyeyinka et al. (2019), who found cake volumes between 390 and 700 cm³ depending on flour type and leavening conditions. These results suggest that the formulated cakes demonstrate standard physical attributes comparable to conventional cakes and those developed using composite or alternative flour blends.

3.2. Proximate composition of cake

The proximate composition of the cake samples (Table 3) varied significantly across all parameters: moisture (12.77–16.80%), fat (22.81–31.57%), protein (6.31–14.14%), crude fiber (0.25–0.86%), ash (0.76–1.12%), and carbohydrates (36.91–52.58%), with energy values ranging from 450.12 to 488.52 kcal/100g. The reported significant difference in moisture content among samples may be attributed to the variation in the moisture content of the composite flour. The flour composition affects the removal of water during baking, depending on the flour type. For example, cake from malted maize had the highest moisture content of 16.80%, probably due to the high-water binding capacity of protein, which is also the highest in the sample. The range of moisture content obtained in this study falls within the general acceptable limit for bakery products and is comparable to the moisture content reported by (Ogbonyomi et al., 2023), who found values between 14.67% and 22.33% in cakes fortified with plantain, soybeans and sesame seeds.

As expected, increasing the percentage inclusion of malted maize flour increased the protein content of cake samples. Specifically, the cake sample made from 100% malted maize flour had the highest protein content. Cake samples that had the inclusion of malted maize flour were significantly ($p<0.05$) higher in protein content compared to other samples. Protein content obtained in this work was consistent with the findings of (Ibrahim et al., 2017), who reported values between 7.0% and 13.2% for cakes enriched with legume flour and the study of (Olaoye et al., 2015) with a range of 8.76-10.50% protein for cakes produced from wheat-malted maize composite. The elevated protein content suggests improved amino acid availability, especially from germinated maize composites, supporting reports by Hübner & Arendt (2013) on nutrient enhancement through malting.

The range of cake fat content obtained in this study is in congruence with that of Ogbonyomi et al. (2023), who reported a range of 25.25-30.08% for cakes fortified with plantain, soybeans, and sesame seed. The use of 50% and 100% nixtamalised flour in cake products caused a significant reduction in the fat component. This could be attributed to the loss of fat during nixtamalized cooking. Practically, nixtamalized cooking of grains could be used to produce low-fat confectionery. Generally, fat content in cake may contribute to improved mouthfeel and energy density (Osunrinade et al., 2020).

Generally, cake crude fibre values were low for all cake samples because of possible conversion of insoluble fibre to its soluble component due to the process of maize malting and nixtamalisation. Crude fibre content remained relatively low, aligning with typical ranges (1.27-1.47%) as reported by Olaoye et al. (2015), who also used malted maize for cake production.

As expected, malting and nixtamalisation increased the ash content of the cake samples when compared with the control sample made from refined wheat flour. It is worthy of note that in terms of the ash content, there was no significant difference between cake samples made from malted maize and nixtamalized maize flours. The ash content obtained in this study corresponds with the previous study of Musa et al. (2019), reporting ash contents below 1.5%, and that of Olaoye et al. (2015), who reported ash contents below 1.60% for cakes from wheat-malted maize composite. The significant increase in ash content in the composite cake samples compared to the 100% refined wheat control could be attributed to the fact that refined wheat flour typically undergoes extensive milling, which removes the mineral-rich bran and germ layers, resulting in a product with depleted micronutrient content (Gupta et al., 2023). As such, the incorporation of malted and nixtamalized maize flours could serve as natural mineral fortification. Further, the elevated ash levels suggest a higher concentration of essential minerals such as calcium, phosphorus, and magnesium. In the nixtamalized samples, this increase is primarily attributed to the absorption of calcium from the alkaline steeping solution, whereas in the malted samples, it likely results from the concentration of endogenous minerals and the degradation of phytic acid. Phytate is a known mineral inhibitor; its reduction during both malting and nixtamalization not only increases the total ash content but also enhances the bioavailability of these minerals within the human digestive tract.

Increasing the percentage of nixtamalised maize flour in the composite caused an increase in the carbohydrate content of cake samples. However, the contrary holds for malted maize flour; as the percentage of malted maize flour increases, the percentage carbohydrate composition decreases. The carbohydrate content of cake samples from nixtamalised maize flour was higher than that of cakes from wheat flour and germinated maize flour, while that of germinated flour was lower than that of wheat flour. Carbohydrate content ranged from 36.91% to 52.58%, which is consistent with the typical carbohydrate profile of cakes (49.01-52.24%) as reported by Olaoye et al. (2015).

The estimated energy values of cake samples were significantly different ($p < 0.05$). The composite flour (50% wheat and 50% malted maize flour) had the highest energy value of the cake samples, while the lowest was from 100% nixtamalized maize flour. This variation could be linked to the variation in the fat content, because the fat content has a significant impact on the energy density of food samples. The calculated energy values (450.12–488.52 kcal) are within the range reported by Obasi & Onwuka (2021), confirming the energy-dense nature of cake products.

3.3. Sensory acceptability of cake sample

Hedonic ranking of sensory attributes of cake samples on a 9-point hedonic scale is presented in Table 4. Closeness of the rankings of panellists to 9 is an indication of their level of likeness, while values closer to one indicate the level of dislike. Panellists evaluated the appearance of the cake samples visually based on the cake's external and internal physical properties, while aroma and taste gave the olfactory and gustative profile to measure the intensity of characteristic flavour. Texture represented the tactile mouthfeel during mastication, while fluffiness served as a measure of aeration and crumb porosity, and the overall acceptability provided an evaluation of all

Table 4: Sensory acceptability of cakes

Sample	Appearance	Texture	Fluffiness	Taste	Aroma	Overall acceptability
CWC	7.76 ± 0.28^{a}	7.6 ± 0.25^{ab}	8.04 ± 0.23^{a}	8.08 ± 0.16^{a}	8.12 ± 0.17^{a}	8.72 ± 0.15^{a}
CMN	7.8 ± 0.23^{a}	7.72±0.23a	7.88 ± 0.24^{ab}	7.92 ± 0.20^{ab}	7.84 ± 0.19^{ab}	8.16 ± 0.18^{ab}
CMG	6.8 ± 0.28^{b}	6.84 ± 0.30^{b}	6.88 ± 0.31^{cd}	6.56 ± 0.34^{c}	6.96 ± 0.29^{c}	7.36 ± 0.26^{c}
CWN	7.16 ± 0.32^{ab}	7.08 ± 0.25^{ab}	6.75 ± 0.27^{d}	7.33 ± 0.25^{abc}	7.33 ± 0.34^{abc}	7.96 ± 0.25^{bc}
CWG	7.08 ± 0.30^{ab}	7.2 ± 0.25^{ab}	7.08 ± 0.32^{abc}	7.2 ± 0.29^{bc}	7.12 ± 0.27^{bc}	7.4 ± 0.26^{c}
CNW	7.76 ± 0.27^{a}	7.6 ± 0.23^{ab}	7.76 ± 0.23^{ab}	7.76 ± 0.27^{ab}	7.88 ± 0.21^{ab}	8.2 ± 0.18^{ab}
CGW	7.24 ± 0.25^{ab}	7.08 ± 0.30^{ab}	7.6 ± 0.25^{abc}	7.24 ± 0.23^{bc}	7.36 ± 0.29^{abc}	7.72 ± 0.29^{bc}

Means with the same superscript within a column are not significantly different ($p < 0.05$).

CWC 100% wheat flour (control); CMN- 50% nixtamalized maize, 50% wheat; CMG - 50% malted maize flour, 50% wheat flour; CWN-75% nixtamalised maize, 25% wheat; CWG-75% malted maize flour, 25% wheat flour; CNW- 100% nixtamalization maize flour; CGW-100% malted maize flour sensory inputs, which indicated the panellists' general satisfaction. For all sensory parameters evaluated by panellists, there was no significant difference between cake samples from 100% wheat and all samples made with the inclusion of nixtamalized maize flour. This is an indication of the suitability and acceptability of the use of nixtamalised maize flour for cake production. On the contrary, the acceptability of cake samples from malted maize flour received lower ratings compared to the control.

3.4. Principal component analysis

The Principal Component Analysis was adopted to highlight the variation in both dependent (physical, proximate and sensory properties) and independent variables (samples) (Osunrinade et al., 2023). The data variance indicated by Principal Component Analysis showed that two components accounted for 80.3% of the total variance. The first principal component (PC1) was responsible for 53.7%, while PC2 accounted for 26.6% of the total variance. The correlation loading of the physical, proximate and sensory properties of cake samples is presented in Table 5. Sensory attributes and carbohydrate correlated positively with the first principal component, while cake's weight and protein had a negative correlation. The positive correlation between carbohydrate content and sensory attributes along the first principal component (PC1) suggests that carbohydrates are the primary drivers of the cake's perceived quality. In Principal Component Analysis (PCA), PC1 typically captures the greatest variance in the data; therefore, this relationship indicates that as carbohydrate levels increase, there is a simultaneous improvement across all hedonic scores. Carbohydrates, specifically reducing sugars, are essential precursors for the Maillard reaction and caramelisation. These reactions are responsible for the development of the characteristic golden-brown crust colour and the generation of volatile aromatic compounds, such as furans and pyrazines, which provide the baked and sweet scents identified by panellists.

In the context of the PCA results, since sensory attributes and carbohydrates are positively correlated with PC1, the negative correlation of weight and protein implies that samples with higher protein levels and greater mass were perceived as lower in sensory acceptability by the panellists. While protein is essential for structure, an increase in protein content often leads to a tougher crumb.

The second principal component correlated positively with cake's volume, moisture, fat and energy, while it had a negative correlation with crude fibre. The positive correlation between volume, moisture, fat, and energy on the second principal component (PC2) identifies this axis as a measure of the nutrient density and fluffiness of the cake samples. The second principal component (PC2) effectively characterised the structural and caloric density of the samples. The strong positive loading of fat, moisture, and volume suggests that fat content was the primary driver for moisture retention and leavening efficiency.

Cake samples made from 100% wheat flour and a composite of 50% wheat and 50% nixtamalized maize flour were in the same quadrant, with all sensory parameters evaluated (Figure 1). As such, indicating comparative acceptability of the cake sample made by the inclusion of 50% nixtamalized maize flour with the

Table 5: Correlation loading of physical, proximate and sensory properties of cake

Variable	Prin 1	Prin 2	Prin 3
Weight	-0.79966	0.17399	-0.47302
Volume	0.17424	0.75311	0.60195
Moisture	-0.45364	0.75405	-0.42569
Fat	-0.64082	0.74522	0.14685
Protein	-0.63499	-0.42502	-0.32106
Crude fibre	-0.12597	-0.773	0.4172
Ash	-0.59255	-0.57966	0.12138
Carbohydrate	0.77126	-0.56913	0.20222
Energy	-0.55031	0.68959	0.4191
Appearance	0.95904	0.07114	-0.18201
Texture	0.9821	-0.07075	-0.08457
Fluffiness	0.83347	0.14853	-0.09502
Taste	0.9619	0.1835	-0.19331
Aroma	0.94022	0.2552	-0.05659
Overall acceptability	0.84819	0.46715	-0.01286

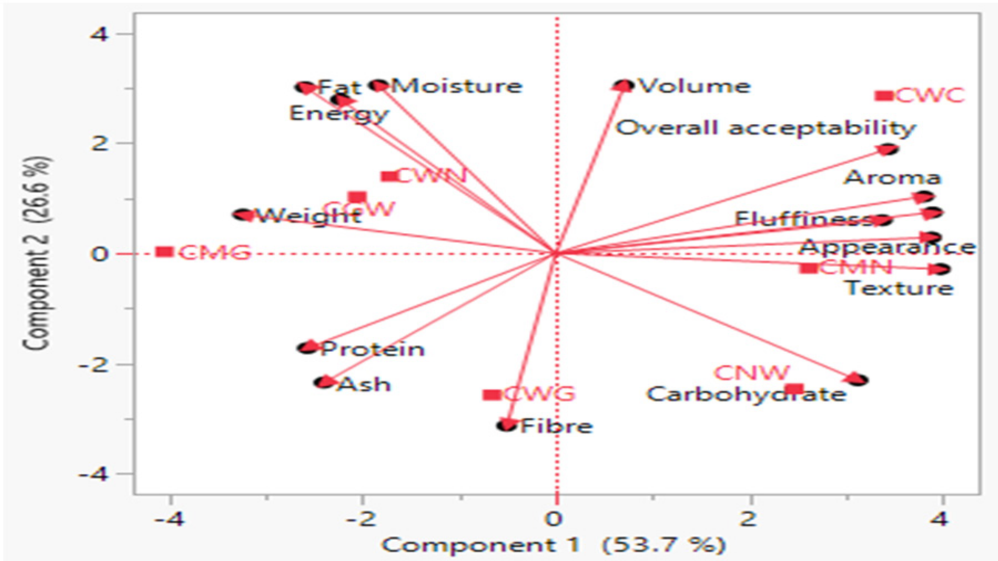

Fig. 1: Biplot showing the principal components analysis of the cake sample.

traditional cake formulation from 100% wheat flour. Similarly, cakes produced from malted maize-wheat-based composite were in the same quadrant as protein and ash. Thus, establishing the influence of germination on the production of nutrient-rich cake.

5. Conclusion

Cake samples produced from various blends of wheat, malted maize and nixtamalized maize showed significant differences in their physical, proximate and sensory attributes. Cake samples from malted maize-wheat blend had higher and more desirable physical properties that are comparable to the control (wheat flour) sample. Increasing the percentage of nixtamalised maize flour in the composite caused an increase in the carbohydrate content of cake samples, while malted maize flour increased the protein content of cake samples. Although there was no significant difference between cake samples made from malted and nixtamalized maize flours in terms of ash content, malting and nixtamalization increased the ash content of the cake samples. For all sensory parameters evaluated by panellists, there was no significant difference between cake samples from 100% wheat and all samples made with the inclusion of nixtamalized maize flour. Principal component analysis established that cake samples made from 100% wheat flour and composite (50% wheat and 50% nixtamalized maize flour) correlated positively with all sensory parameters evaluated. Similarly, cakes produced from malted maize-wheat-based composite were in the same quadrant with protein and ash content. Thus, malted and nixtamalized maize flours can be utilised to develop nutritionally enhanced cakes without compromising sensory quality.

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