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Evaluation of Proximate Composition, Minerals Content and Sensory Properties of Cake Formulated with Fermented Sorghum Flour

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ABSTRACT

Objective: This study aimed to determine the proximate composition, mineral content, and sensory attributes of composite cake samples prepared from varying proportions of fermented sorghum and wheat flours.

Materials and Methods: Six cake formulations were produced using fermented sorghum flour and wheat flour: BBM (30:70), BBS (40:60), BBT (10:90), BBZ (20:80), BBL (100% fermented sorghum flour), and BBY (100% wheat flour). Fermented sorghum flour was obtained through a 72 hrs fermentation process. All samples were evaluated for proximate composition, mineral content and sensory properties using standard analytical procedures.

Results: Fermentation significantly ($p<0.05$) enhanced the mineral composition of the cake samples. Calcium ranged from 123-330 mg/100 g, phosphorus from 88.33-200 mg/100 g, and potassium from 126-210 mg/100 g. The control sample (BBY, 100% wheat flour) contained 217 mg/100 g calcium, 177 mg/100 g phosphorus, and 142 mg/100 g potassium. BBL (100% fermented sorghum flour) exhibited the highest mineral concentrations. Sensory evaluation indicated that all samples were generally acceptable to panelists.

Conclusion: The findings demonstrate that fermented sorghum flour is a nutritionally valuable ingredient capable of enhancing the mineral content of bakery products. Its use-either alone or in combination with wheat flour-can produce cakes with acceptable sensory characteristics, supporting its potential application in functional food development.

INTRODUCTION

Cake is a baked sweet food product typically prepared from flour, sugar, and various other ingredients. Historically, cakes originated as modified forms of bread; however, they now encompass a wide range of formulations that may be simple or highly elaborate, sharing characteristics with other dessert categories such as meringues, pastries, pies and custards. According to Amazian[1], fundamental cake ingredients include flour but ter, oil or margarine, sugar, eggs, a liquid component and leavening agents such as baking soda or baking powder. Additional ingredients commonly incorporated into cake formulations include dried, candied, or fresh fruits, nuts, cocoa and flavor extracts such as vanilla, with numerous possible substitutions for the primary ingredients. Cakes may also be filled with various fillings, coated with buttercream or other types of icing and decorated as desired. They are generally classified into categories such as butter cakes, sponge cakes, chiffon cakes and chocolate cakes, predominantly based on ingredient composition and mixing methods[2]. Cake remains one of the most widely consumed bakery products globally and both ingredient selection and processing techniques significantly influence its structure and sensory quality.

Wheat flour, a principal component of cakes and many other baked goods, has been associated with adverse health effects in individuals who cannot adequately digest wheat gluten in the small intestine. Wheat consumption is increasingly linked

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to a range of health conditions, including heart disease and gastrointestinal disorders, alongside a rising prevalence of celiac-like symptoms[3]. In addition, wheat production in Nigeria is limited by climatic constraints, necessitating large-scale importation to meet domestic demand. Consequently, substantial foreign exchange is expended annually on wheat imports[4]. To mitigate this dependency, efforts have focused on the development of composite flours produced by partially substituting wheat flour with flours derived from locally cultivated, protein-rich crops, thereby reducing reliance on imported wheat[5]. Sorghum (Sorghum bicolor L. Moench) is a cereal grain belonging to the subfamily Panicoideae within the family Gramineae. After wheat, rice, maize and barley, sorghum is recognized as the fifth most important cereal crop worldwide[6]. It can be processed into flour with high storage stability and is widely cultivated in Northwestern and Northeastern Nigeria as an affordable source of calories and a suitable ingredient for weight management. However, sorghum contains several anti-nutritional factors, including tannins, trypsin inhibitors, cyanogenic glycosides, phytic acid and oxalates, which must be reduced or eliminated prior to its use in food applications[7]. Fermentation has been shown to decrease these anti-nutritional components while enhancing the functional properties of sorghum flour, as reported by Opeyemi et al.[8]. Fermented sorghum flour therefore holds potential for incorporation into bakery products such as cakes and snack foods. This study sought to evaluate the proximate composition, mineral profile and sensory characteristics of composite cake samples formulated with different ratios of fermented sorghum and wheat flours.

MATERIALS AND METHODS

Sources of raw materials: Red sorghum grain, sugar, margarine, eggs, milk, baking powder, nutmeg powder and butterscotch flavor used in this study were procured from the Eke Awka Market in Awka, Anambra State.

Production of fermented sorghum flour: The sorghum grains were sorted and cleaned to remove foreign materials. Fermentation was carried out at ambient temperature by soaking the cleaned grains in water for 72 hrs (3 days), with the soaking water replaced every 24 hrs, following the traditional Sudanese germination method described by Elkhalifa et al.[9]. After fermentation, the grains were dried in a hot-air oven at 56°C for 6 hrs and subsequently milled into flour. The resulting flour was sieved through a 0.4 mm mesh to obtain a fine, uniform particle size, then packaged for later use. The production process for the fermented sorghum flour is presented in Fig. 1.

Production of cakes: Cakes were prepared following the method described by Ceserani et al.[10]. The formulation consisted of flour (30 g), margarine (20 g), egg (20 g), sugar

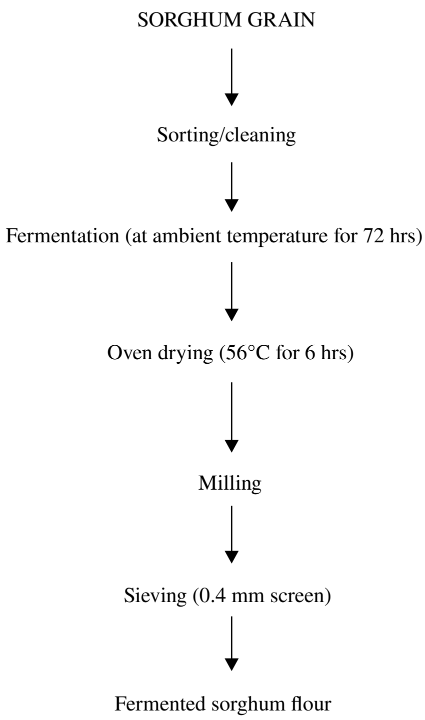

Fig 1: Production of fermented sorghum flour

(12 g), milk (10 g) butterscotch flavor (1.5 g) and baking powder (0.5 g). All dry ingredients were weighed and mixed thoroughly in one bowl. In a separate bowl, margarine and sugar were creamed together, after which half of the beaten egg was incorporated. The dry ingredients were gradually added to the creamed mixture and blended. The remaining egg was then added and mixed thoroughly. Finally, milk and flavoring were incorporated and the batter was mixed to uniformity. The prepared batter was transferred into greased baking pans and baked in an oven at 160°C for 20 min.

Proximate composition of the cake samples: Moisture, crude protein, crude fiber, crude fat and ash contents were determined according to AOAC[11]. Carbohydrate content was calculated by difference, subtracting from 100 the sum of the percentages of moisture, crude ash, protein, fat and fiber:

Carbohydrate (%) = 100-[Moisture (%) + Crude Protein (%)+Crude Fat (%) + Crude Fiber (%) + Crude Ash (%)]

Mineral composition of the cake samples: Mineral analysis was performed following the method described by the Association of Official Analytical Chemists[11]. Ashed samples were dissolved in 10 mL of 20% HCl, filtered into a 100 mL volumetric flask and diluted to volume with deionized water. The resulting solution was used for mineral determination. Calcium (Ca), phosphorus (P) and potassium (K) were quantified using a standard flame emission photometer (PFP7), JENWAY Model 410 (South Africa). Calcium chloride and potassium chloride served as standards. Phosphorus was determined colorimetrically using a Spectro 20 (Gallenkamp, UK), with KH PO as the standard. Calcium was also analyzed using an atomic absorption spectrophotometer (AAS Model SPA). Mineral contents were expressed as mg per 100 g of sample.

Sensory evaluation of the cake samples: Sensory evaluation was conducted to assess consumer acceptability. Twenty panelists-comprising students and staff of the Food Science and Technology Laboratory, Nnamdi Azikiwe University, Awka-participated in the evaluation. All panelists were familiar with cake and consumed it regularly. The cakes were evaluated simultaneously by fifteen of the panelists using a nine-point hedonic scale. Samples were served on saucers and panelists were instructed to rinse their mouths with potable water between samples. Each panelist completed a sensory evaluation form and rated the cakes based on color, taste, aroma, mouthfeel and overall acceptability. The nine-point hedonic scale corresponded to: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely.

Statistical analysis: Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 22. One-way analysis of variance (ANOVA) was employed to determine significant differences among sample means at $p<0.05$ and significant means were separated using the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

Proximate composition: The proximate composition of cakes prepared with fermented sorghum flour and wheat flour is presented in Table 1. Ash content, an indicator of the mineral composition of food samples, differed significantly among all treatments ($p<0.05$). Ash values ranged from 1.44-3.00%. The cake produced from 100% sorghum flour (BBL) exhibited the highest ash content (3.00%), whereas the cake prepared from 100% wheat flour (BBY) had the lowest ash content (1.44%). This observation suggests that sorghum flour is inherently richer in mineral constituents than wheat flour.

However, the composite flour samples did not follow the expected trend. Despite pure sorghum flour yielding higher ash content than pure wheat flour, increasing substitution with fermented sorghum flour did not consistently elevate ash levels. This irregular pattern may be attributed to variations in mineral ion concentrations in the soils where the source crops were cultivated[12].

Moisture content ranged from 13.05-22.17%, with all samples showing significant differences at the $p<0.05$ level. Sample BBY recorded the lowest moisture content (13.05%), suggesting that wheat flour may possess a lower moisture-holding capacity compared with sorghum flour, resulting in a higher proportion of free water that was more readily volatilized during baking. The composite samples, however, did not exhibit a consistent moisture trend. The observed moisture values are similar to those previously reported for different sorghum varieties by Jimoh and Abdullahi[13].

Crude fiber content ranged from 0.20-1.60%. There was no significant difference between BBM and BBY ($p>0.05$), while all other samples differed significantly from each other. No clear pattern was evident across the composite formulations.

Crude fat values differed significantly across all samples ($p<0.05$), ranging from 23.33-28.34%. BBY exhibited the lowest crude fat content (23.33%). These findings indicate that sorghum flour contributes more crude fat to the cakes than wheat flour, consistent with the observations of Yuan et al.[14]. As with other parameters, no defined trend emerged among the composite samples.

Crude protein content ranged from 5.45-12.12%. BBL exhibited the highest protein value (12.12%), whereas BBY recorded the lowest value (5.45%). These values align with previously reported data for sorghum-based products[13]. The results indicate that increasing the proportion of fermented sorghum flour enhances the crude protein content of the cake, demonstrating its potential to improve the protein value of baked goods.

Carbohydrate content represented the major nutritional component of the samples, ranging from 38.07-49.88%. No significant difference ($p>0.05$) was observed between BBL and BBY; however, all other samples differed significantly from both controls and from one another.

Table 1: Proximate composition of the cake samples

Sample WF:FSF	Ash content (%)	Moisture content (%)	Fiber content (%)	Fat content (%)	Protein content (%)	Carbohydrate content (%)
BBL	3.00 ± 0.00^{a}	18.34 ± 0.00^{d}	0.91 ± 0.01^{c}	25.09 ± 0.01^{c}	12.12 ± 0.00^{f}	47.22 ± 0.01^{a}
BBT	1.90 ± 0.00^{a}	20.66 ± 0.00^{b}	0.60 ± 0.10^{d}	28.11 ± 0.01^{b}	10.67 ± 0.00^{b}	38.07 ± 0.00^{d}
BBZ	1.99 ± 0.01^{d}	17.22 ± 0.02^{e}	1.60 ± 0.00^{a}	28.11 ± 0.01^{c}	8.43 ± 0.00^{d}	42.64 ± 2.00^{c}
BBM	2.57 ± 0.01^{c}	20.12 ± 0.00^{c}	0.38 ± 0.29^{c}	26.00 ± 0.01^{d}	9.89 ± 0.01^{c}	40.52 ± 0.86^{d}
BBS	2.90 ± 0.00^{b}	22.17 ± 0.00^{a}	1.20 ± 0.00^{b}	28.34 ± 0.01^{a}	7.13 ± 0.01^{e}	38.28 ± 0.01^{e}
BBY	1.44 ± 0.01^{f}	13.05 ± 0.00^{f}	0.20 ± 0.00^{c}	23.33 ± 0.00^{f}	5.45 ± 0.00^{a}	49.88 ± 0.01^{a}

Values are presented as mean ± standard deviation of duplicates. Values on the same column with different superscripts are significantly different ($p<0.05$), Where: WF: Wheat flour, FSF: Fermented sorghum flour, BBL: 100% FSF, BBT: 10% WF: 90% FSF, BBZ: 20% WF:80% FSF, BBM: 30% WF:70 % FSF, BBS: 40% WF:60% FSF and BBY: 100% WF

Table 2: Mineral composition of the cake samples

Sample ratio WF:FSF	Calcium (mg/100 g)	Phosphorus (mg/100 g)	Potassium (mg/100 g)
BBL	330.00±0.00[c]	200.00±0.00[b]	210.00±0.00[c]
BBT	123.00±1.00[f]	102.67±2.31[e]	127..00±0.00[e]
BBZ	146.00±0.01[e]	117.00±0.57[a]	180.00±0.00[b]
BBM	200.00±1.00[d]	124.67±1.52[c]	126.33±1.54[e]
BBS	320.00±1.00[b]	88.33±0.58[f]	136.67±0.58[d]
BBY	217.00±1.00[a]	177.00±1.00[a]	142.67±2.31[a]

Values are presented as mean±standard deviation of duplicates, Values on the same column with different superscripts are significantly different (p<0.05), Where: WF: Wheat flour, FSF: Fermented sorghum flour, BBL: 100% FSF, BBT: 10% WF:90% FSF, BBZ: 20% WF:80% FSF, BBM: 30% WF:70 % FSF, BBS: 40% WF:60% FSF and BBY: 100% WF

Table 3: Sensory evaluation of the cake samples

Samples code	Colour	Taste	Aroma	Mouthfeel	General acceptability
BBL	5.80±1.42[b]	6.13±1.24[b]	6.40±1.12[a]	6.13±1.88[ab]	6.30±1.80[bc]
BBT	6.47±1.96[b]	6.87±1.55[ab]	6.67±1.11[a]	6.93±1.62[a]	7.06±1.50[ab]
BBZ	7.93±1.39[c]	4.80±1.70[c]	4.93±1.83[b]	5.07±2.05[b]	5.30±1.62[c]
BBM	5.67±1.63[b]	6.93±1.83[ab]	6.80±1.32[a]	7.20±1.15[a]	6.93±1.30[a]
BBS	6.20±1.78[b]	6.53±1.64[ab]	6.47±0.64[a]	6.20±1.70[ab]	6.73±1.22[ab]
BBY	6.22±1.91[a]	7.42±0.80[a]	7.07±0.80[a]	6.73±1.30[a]	7.80±1.15[a]

Values are presented as mean±standard deviation of duplicates, Values on the same column with different superscripts are significantly different (p<0.05), Where: WF: Wheat flour, FSF: Fermented sorghum flour, BBL: 100% FSF, BBT: 10% WF:90% FSF, BBZ: 20% WF:80% FSF, BBM: 30% WF:70% FSF, BBS: 40% WF:60% FSF and BBY: 100% WF

Overall, the proximate analysis suggests that cakes formulated with fermented sorghum flour or sorghum-wheat composites are nutritionally superior to those made exclusively from wheat flour, exhibiting generally higher values for most evaluated components except carbohydrate.

Mineral composition: Table 2 presents the mineral composition (calcium, phosphorus and potassium) of the cake samples. The calcium content varied significantly among all six samples (p<0.05). The cake produced from 100% fermented sorghum flour (BBL) contained the highest calcium level (330.00 mg/100 g), followed closely by BBS with a mean value of 320.00 mg/100 g. The remaining samples (BBM, BBT, BBZ and BBY) exhibited calcium contents ranging from 123 to 217 mg/100 g.

Phosphorus content also differed significantly across the samples (p<0.05). BBL (100% fermented sorghum flour) had the highest phosphorus value (200.00 mg/100 g), followed by BBY (100% wheat flour) with a mean of 177.00 mg/100 g. Sample BBF recorded the lowest phosphorus content (88.33 mg/100 g).

For potassium, BBL again demonstrated the highest content (210.00 mg/100 g), followed by BBZ (180.00 mg/100 g). BBM showed the lowest potassium value (126.3 mg/100 g). No significant difference (p>0.05) was observed between BBM and BBT, whereas BBL, BBS, BBZ and BBY differed significantly (p<0.05) from both BBM and BBT. Overall, sample BBL consistently exhibited the highest mineral concentrations among all treatments.

Sensory evaluation: Table 3 summarizes the sensory evaluation results for cakes prepared with fermented sorghum and wheat flour. For color, no significant differences (p<0.05) were observed among the control sample BBY (6.22), BBM (5.67), BBL (5.80), BBS (6.20) and BBT (6.47). This indicates that these formulations compared favorably with the control (100% wheat flour) in terms of appearance.

Taste scores similarly showed no significant differences (p>0.05) among BBY (7.42), BBM (6.93), BBL (6.13), BBS (6.53) and BBT (6.87), suggesting that fermentation did not adversely influence the taste of the cake samples. Samples BBS (6.53) and BBT (6.87) were not significantly different from each other and were statistically similar to BBM, BBL and BBY but both differed significantly from BBZ (20% wheat flour and 80% fermented sorghum flour).

A similar pattern was observed for aroma: BBM, BBL, BBS, BBT and BBY did not differ significantly from one another, although all were significantly different from BBZ. Mouthfeel scores ranged from 5.07-7.20 and may have been influenced by variations in moisture content among samples. Regarding overall acceptability, the control sample BBY obtained the highest score (7.80). Its acceptability did not differ significantly from BBM, BBS and BBT, indicating that these formulations were well accepted by the panelists. This aligns with findings by Mongi et al.[15], who reported similar consumer acceptability for cake products formulated with alternative grains. BBZ was the least accepted sample, although its score did not differ significantly from that of BBL.

CONCLUSION

The findings of this study indicate that cake samples with higher proportions of fermented sorghum flour were generally more acceptable to the sensory panel. This increased acceptability may be attributed to the enhanced functional and sensory attributes imparted by fermentation. Notably, formulations with greater levels of fermented sorghum flour substitution demonstrated improved taste, mouthfeel and color and were rated more favorably than those containing higher proportions of whole wheat flour. Fermentation likely contributed to improved nutrient accessibility in the composite cakes. Samples with higher whole wheat flour content exhibited comparatively lower scores for color and taste. In contrast, cakes formulated with higher levels of fermented sorghum flour showed better shelf stability, maintaining freshness for up to four days post-production, whereas other samples exhibited early signs of rancidity. Overall, the use of fermented sorghum flour in cake formulation demonstrates potential for improving both the nutritional and sensory quality of baked products while enhancing product stability.

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