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Optimization of proximate composition, physico-chemical properties and mineral profiles of 'Garri', soy-cake and millet flour blends for potential functional dough meal

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Abstract

This study investigated effects of varying proportions of "Garri", soy cake and whole millet flours on proximate composition, physico-chemical properties and mineral profiles of their blends as potential material for preparation of functional dough meal. Blends were optimized for protein (10-20%) and fibre (3-5%), using Design Expert Version 6.0.8. and variables "garri" (56-65%), soy cake (13-24%) and whole millet (11-22%) flours, which generated 14 blends. 100% 'garri' flour and three blends with highest protein and fibre contents were evaluated for proximate composition, physico-chemical properties and mineral profiles including mineral safety index of selected minerals. Protein and fibre contents of blends increased with increased proportions of soy cake and millet flours. Protein contents of blends increased (15.55–15.83%), while carbohydrate reduced (73.73–74.06% significantly ($p < 0.05$), compared to 100% "garri" flour (2.11% and 92%), respectively. 100% "garri" flour had significantly ($p < 0.05$) higher values for most functional and pasting parameters, compared to the blends, but no significant ($p > 0.05$) difference among the blends for most pasting properties. Swelling index correlated positively with both carbohydrate content and water absorption ($r = 0.60$). There was significant ($p < 0.05$) difference between mean calculated and standard MSI values for all minerals, while sample GSM-1 had highest calculated MSI values for all minerals except Ca and Na. Varying proportions of "garri", soy cake and millet flours significantly ($p < 0.05$) altered the proximate composition, functional properties and mineral profiles of the blends but did not significantly ($p > 0.05$) affect most pasting parameters.

Keywords: Flour blends; Functional dough meal; Mineral profiles; Optimization; Physico-chemical properties; proximate composition

1. Introduction

Cassava (Manihot esculenta Crantz), is a major staple food in different parts of Africa, including Nigeria, where it is used for food, feed and a major input in small-scale agro-allied processing ventures, and source of poverty alleviation and food security [1]. Consumption of cassava in Nigeria is more common in the southern part, where it is used in different forms, which are generally acceptable to different classes of the populace [2]. Nigeria is ranked the world's largest producer of cassava, accounting for over 59 million tons, or over 20% of total world production, in 2017, with an increase of over 35% production over a 10-year period [3]. The most important and widely consumed product of cassava is "Garri", toasted pre-gelatinized, granular flour, made from fermented grated cassava mash or pulp [4]. It is consumed mostly as a main meal, in form of dough meal, or swallow, ("Eba") and eaten with different types of soups depending on the area. "Garri", like other cassava products contain mainly carbohydrate and extremely low in most macro and micro nutrients including protein, vitamins and minerals [5], which will adversely affect the nutritional status of consumers. Soybean (Glycine max Merril.) is a tropical crop used widely as food and for animal feed, and contains wide varieties of important nutrients [6, 7]. The importance of soy bean as a cheap source of improving protein of plant-based diets has been acknowledged by many previous studies [6, 8, 9, 10, etc.]. Consumption of diets high in

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soybean has been linked with low blood glucose concentration reduction in prevalence of common degenerative diseases like diabetes, atherosclerosis, cancer and heart-related ailments [11, 12].

Millets, especially pearl millet (Pennisetum glaucum), are important sources of essential nutrients such as amino acids, vitamins like thiamine, niacin, and riboflavin as well as minerals such as calcium, iron and phosphorus as well as dietary fibre [13, 14]. Health benefits of millets due to their high contents of fibre, phenolic compounds, anti-oxidants and meta-ion-reducing powers have been acknowledged [15, 16]. The role of dietary fibre in management of diabetes, lowering blood glucose concentration, improvement of insulin sensitivity, reduction in harmful cholesterol and control of other diseased conditions have been reported [17]. The prevalence of these diseases in different parts of the world, including Nigeria is becoming alarming, which necessitates the need for alternative method for their control and management instead of expensive synthetic drugs with serious adverse effect when used for a long period of time. Many previous studies have shown that blends of indigenous plant-based materials are effective for the control and reduction of the prevalence of these diseases [9, 10, 18]. There is the need to explore the potentials of other commonly consumed indigenous staples in this regard. Addition of soy cake and whole millet flours to “garri” flour will not only improve the nutrient load of the dough meal prepared from the composite flours and subsequently the nutritional status of the consumers, such dough meal is also expected to have some functional benefits. The objective of this preliminary study was to optimize the proximate compositions, physico-chemical properties and mineral profiles of blends of “garri”, soy cake and whole millet flours, as potential ingredients for functional dough meal, using response surface methodology.

2. Material and methods

2.1. Materials and sources

The materials used for this study were white “garri”, soy cake and pearl millet *(Pennisetum glaucum).*” Garri” and pearl millet were purchased from Oyingbo Retail Market on Lagos Mainland, Lagos, while soya cake was obtained from Agro Allied Nig. Ltd., Ibadan, Nigeria.

2.2. Preparation of samples

Soy cake flour was produced by cleaning the soy cake to remove dirt and drying in a cabinet dryer (Carlisle CA2 5DU, Mitchel Dryers Ltd, England, 3695-010) at 62±1.5°C for 6hrs. The cleaned soy cake and ‘garri” were separately milled in a grinding hammer mill (Type S/03 7.5HP, Petrel Limited, Birmingham England, 2121A), and sieved using a Test Sieve Shaker ((Endecotts, England). Materials which passed through sieve of mesh size 212µm were collected. Whole pearl millet flour was produced using a modified method of Chauhan and Sarita (2018), by cleaning to remove dirt and damaged grains followed by milling, without sieving [10] . The three flours were packaged in a high-density polyethylene bag and stored in a cool (25-27°C), moisture-free environment until used. Flour blends were prepared using D-Optimal model of Mixture Design of Design Expert Version 6.0.8., based on the optimization of protein from soy cake flour and fibre from whole millet flour, using variables “garri” flour (56-65%), soy cake flour (13-24%) and whole millet flour (11-22%), which targeted protein and fibre contents of 10-20% and 3-5% in the final product. The 14 blends generated were evaluated for protein and fibre contents and three blends with the highest protein and fibre contents were selected and for further studies, along with 100% “garri” flour.

2.3. Determination of protein and fibre contents of blends and proximate compositions of selected samples

Protein and fibre contents of blends generated by Design Expert and proximate composition of selected blends and 100% “garri” flour were determined using standard AOAC (2015) [19]. Carbohydrate content was obtained by difference and results expressed on dry weight basis, except for moisture.

2.4. Determination of functional properties of samples

Packed bulk densities of flour samples were determined as described by [20]. Water and oil absorption capacities, swelling power and solubility index were determined using the methods described by [21], dispersibility was determined by the method of [22], while reconstitution index was determined by the method previously described by [23].

2.5. Determination of pasting properties of samples

Pasting properties of the flour samples were determined using the Rapid Visco Analyzer (RVA), and the curves obtained were used to obtain the peak viscosity, trough viscosity, final viscosity, breakdown, setback viscosity, peak time and pasting temperature [24].

2.6. Determination of minerals and mineral-mineral ratios

2.7. Mineral contents for Ca, Zn and Fe were measured by atomic absorption spectrophotometer (AAS) (Analytikjena AG, Germany) according to the method of [25]. Sodium and potassium were determined using flame emission photometer with NaCl and KCl as the standards [19], while Ph was determined using Vanodo-Molybdate method. Mineral-mineral ratios were calculated by dividing the amount of each mineral by the respective mineral. [K:Ca + Mg)] milli-equivalent ratio was calculated according to the method described by [26].

2.8. Calculation of Mineral Safety Index

Mineral safety index (MSI) of samples for Ca, Fe, Mg, Ph Na and Zn were calculated using equation 1 [27]. The standard MSI values for the minerals are: Ca (10), Fe (6.7), Mg (15), Ph (10), Na (4.8), and Zn (33) [26].

$$MSI = \frac{MSI_{standard\,value}\ x\ Experimental\ value}{Recommended\ Adult\ Intake(RAI)} \qquad \text{(Eq. 1)}$$

2.9. Statistical Analysis

Data were collected in triplicates and analyzed using the IBM SPSS version 23 (SPSS, 2015), and results expressed as mean ± s.d. Significant difference between means was determined using the one-way analysis of Variance (ANOVA), while means were separated using the New Duncan Multiple Range Test (NDMRT) at 0.05.

3. Results and discussion

3.1. Protein and fibre contents of blends and proximate compositions of selected samples

The protein and fibre contents of the flour combinations or blends generated by optimization are presented in Table 1, while the proximate compositions of three selected blends and 10% 'garri" flour are presented in Table 2. From Table 1, protein and fibre contents increased in the blends with high proportions of soy cake and whole millet flours, which could be attributed to the high contents of protein in soya bean [6, 29] and millet [14, 30], respectively. As shown on this Table, the three blends with the highest protein and fibre contents are RUNS 1, 2 and 11, which were coded GSM-1, GSM-2 and GSM-3 respectively and used for further studies. From Table 2, there were significant differences ($p < 0.05$) for proximate compositions between three selected blends and 100% 'garri' flour on one hand and between the selected blends on the other. The moisture contents of all the samples, which ranged between 9.38% for GSM-1 (56.00:22.00:22.00) to 10.18% for 100% 'garri" flour were within the level for safe storage of flours without encountering deterioration, especially from moulds [31]. There was significant ($p < 0.05$) increase in the protein contents of the blends, which ranged between 15.83% for sample GSM-1 to 16.25% for sample GSM-2, compared to 2.11% for 100% 'garri' flour. The fibre contents also significantly ($p < 0.05$) increased in the blends (4.14, 4.27 and 4.19% for GSM-1, GSM-2 and GSM-3 respectively), compared to 2.38% for 100% 'garri' flour, although there was no significant difference ($p > 0.05$) among the blends for this parameter. Similar increases in the protein and fibre contents of plant-based food formulations by addition of soy cake and whole millet flours have been previously reported [8, 9, 29, 32, etc.]. The high protein and fibre contents of the blends will improve the nutritional status of the potential consumers of the dough meal prepared from the flour blends.

3.2. Functional properties of selected flour blends

The functional properties of selected blends and 100% "garri" flours are presented in Table 3, which indicated significant differences ($p < 0.05$) between the flour blends and 100% 'garri" flour for all functional properties determined, and between the blends except for bulk density and water absorption. The bulk densities of the blends are 0.76, 0.77 and 0.79g/ml for samples GSM-1, GSM-2 and GSM-3 respectively, compared to a value of 0.68g/ml for 100% 'garri' flour. The high significantly ($p < 0.05$) higher bulk densities of blends compared to 100% 'garri" flour could be attributed to the presence of soy cake and whole millet flours, and consequently higher fibre contents. The bulk densities of the blends are similar to the values obtained for blends of wheat, pigeon pea and cassava cortex flours for functional snack [33], but slightly higher than the bulk densities for blends of quality protein maize, soy cake and whole millet flours reported by [32] and the maximum standard of 0.70g/ml for flours.

Table 1 Protein and fibre contents of blends of 'GARRI', soy cake and whole millet flours

Experimental Runs	"Garri" flour (%)	Soy cake Flour (%)	Pearl Millet Flour (%)	Crude protein content (%)	Crude fibre content (%)
1	56.00	22.00	22.00	14.36	3.78
2	60.50	24.00	15.50	14.66	3.82
3	60.50	17.50	22.00	12.27	3.48
4	65.00	18.50	16.50	12.19	3.47
5	65.00	13.00	22.00	10.18	3.19
6	62.75	16.88	20.37	11.82	3.42
7	65.00	13.00	22.00	10.21	3.16
8	62.75	22.38	14.87	13.84	3.70
9	60.50	20.75	18.75	13.46	3.65
10	65.00	24.00	11.00	14.21	3.76
11	58.25	22.38	19.37	14.32	3.80
12	65.00	18.50	16.50	12.24	3.40
13	56.00	22.00	22.00	14.46	3.85
14	65.00	24.00	11.00	13.98	3.80

Table 2 Proximate composition of blends of 'garri', soy cake and whole millet flours

Parameters/Samples	GSM-1	GSM-2	GSM-3	CTL-1
Moisture content (%)	9.38 ± 0.10^{d}	9.94 ± 0.07^{b}	9.58 ± 0.15^{c}	10.18 ± 0.18^{a}
Crude protein (%)	15.80 ± 0.10^{b}	16.25 ± 0.22^{a}	15.83 ± 0.04^{b}	2.11 ± 0.03^{c}
Crude fat (%)	3.26 ± 0.05^{a}	3.04 ± 0.04^{c}	3.15 ± 0.06^{b}	1.20 ± 0.07^{d}
Total ash (%)	3.07 ± 0.03^{b}	3.20 ± 0.04^{a}	3.11 ± 0.09^{ab}	1.97 ± 0.06^{c}
Crude fibre (%)	4.14 ± 0.05^{a}	4.27 ± 0.07^{a}	4.19 ± 0.11^{a}	2.38 ± 0.10^{b}
Carbohydrate (%)	73.73 ± 0.08^{b}	73.24 ± 0.11^{b}	74 06 ± 0.30^{b}	92.34 ± 0.08^{a}

Means of triplicate determinations are reported and expressed on dry weight basis except for moisture Means with different superscripts along rows are significantly different ($p < 0.05$) GSM-1: = 56.00 GRF: 22.00SCF: 22.00WMF; GSM-2: = 60.50GRF: 24.00 SCF: 15.50WMF GSM-3: = 58.25GRF : 22.38SCF : 19.37WMF; CTL-1 = 100% "Garri" flourGRF= "Garri" flour; SCF = Soy cake flour; WMF = Whole millet flour.

There was significant difference ($p < 0.05$) between the flour blends and 100% 'garri' flour, but no significant difference ($p > 0.05$) between the blends for water absorption capacity, which had the values of 2.32, 2.33 and 2.36ml/g, compared to 2.90ml/g for 100% "garri" flour. This shows that varying substitution levels in the blends had no significant influence ($p < 0.05$) on the blends, which contrasted reports of previous studies of legume-fortified composite flours (10, 32, 34]. The slightly but significantly ($p < 0.05$) higher water absorption for 100% "garri" flour is most probably due to its higher carbohydrate, with which most water absorbed by a food system has been associated, compared to other food components like protein and fibre [35]. There were significant differences ($p < 0.05$) for swelling capacity between the blends (4.24% for sample GSM-2 and 4.49% for sample GSM-1), and 100% "garri" (6.72%), and between the blends. The significantly ($p < 0.05$) lower swelling values for the blends could be attributed to the presence of soy cake flours in the blends compared to 100% "garri" flour. Legume flours have been associated with restricted swelling [36, 37], which will most likely affect the pasting properties of the flours during preparation of their dough meal [34, 35]. These results are similar to the observations of [32], who reported lower swelling capacity values in blends of quality protein maize, soy cake and whole millet flours and [33], 2020, for blends of wheat, soy cake and cassava cortex flours with higher proportions of soy cake flour. Swelling index correlated positively with both water absorption capacity and carbohydrate content (Table 2), with r = 0.60 in both cases. The higher the carbohydrate contents of a food system, the higher the water absorption and consequently the swelling capacity. Dispersibility correlated positively with reconstitution index (r = 0.94).

3.3. Pasting properties of selected blends

The pasting properties are presented in Table 4. These results showed that while there were significant differences ($p < 0.05$) between the blends and 100% “garri” flour for all pasting properties, there was no significant difference ($p > 0.05$) among the blends for almost all pasting properties, except the pasting temperature for which sample GSM-1 had slightly but significantly ($p < 0.050$) higher value (82.55^{o}C), compared to other two blends which had 80.54^{o}C and 81.32^{o}C for samples GSM-2 and GSM-3 respectively.

Table 3 Functional properties of blends of ‘garri’, soy cake and whole millet flours

Parameters/Samples	**GSM-1**	**GSM-2**	**GSM-3**	**CNT-1**
Packed bulk density (g/ml)	0.76 ± 0.02^{b}	0.77 ± 0.01^{b}	0.79 ± 0.01^{b}	0.68 ± 0.03^{b}
Water Absorption Capacity (ml/g)	2.32 ± 0.05^{b}	2.33 ± 0.16^{b}	2.36 ± 0.09^{b}	2.90 ± 0.14^{a}
Oil Absorption Capacity (ml/g)	0.55 ± 0.04^{b}	0.62 ± 0.01^{a}	0.60 ± 0.02^{a}	0.96 ± 0.03^{a}
Swelling capacity (%)	4.49 ± 0.00^{b}	4.24 ± 0.08^{c}	4.44 ± 0.12^{b}	6.72 ± 0.14^{a}
Water solubility index (%)	6.54 ± 0.20^{a}	5.62 ± 0.12^{b}	5.18 ± 0.01^{c}	4.06 ± 0.15^{d}
Reconstitution index (ml)	31.64 ± 0.54^{d}	36.67 ± 1.53^{c}	42.80 ± 1.50^{b}	48.67 ± 1.24^{a}
Dispersibility (%)	54.67 ± 1.58^{d}	58.33 ± 1.25^{c}	60.67 ± 1.15^{b}	69.33 ± 1.15^{a}

Means of triplicate determinations are reported and expressed on dry weight basis except for moisture. Means with different superscripts along rows are significantly different ($p < 0.05$); GSM-1: = 56.00GRF : 22.00SCF : 22.00WMF; GSM-2: = 60.50GRF: 24.00 SCF : 15.50WMF; GSM-3: = 58.25GRF : 22.38SCF : 19.37WMF; CTL-1 = 100% “Garri” flour; GRF= “Garri” flour; SCF = Soy cake flour; WMF = Whole millet flour.

Table 4 Pasting characteristics of blends of ‘garri’, soy cake and whole millet flours

Parameters/Samples	**GSM-1**	**GSM-2**	**GSM-3**	**CNT-1**
Peak Viscosity (a)(RVU)	20.98 ± 0.15^{b}	21.84 ± 0.09^{b}	22.21 ± 0.13^{b}	141.42 ± 6.50^{a}
Trough Viscosity (b)(RVU)	18.54 ± 0.21^{b}	19.63 ± 0.13^{b}	20.63 ± 0.21^{b}	121.30 ±4.38^{a}
Final viscosity (c)(RVU)	43.92 ± 0.17^{b}	45.38 ± 0.46^{b}	45.87 ± 0.63^{b}	197.79 ± 10.21
Breakdown (a – b) (RVU)	2.46 ± 0.04^{b}	2.21 ± 0.04^{b}	1.59 ± 0.09^{b}	20.13 ± 2.13^{a}
Setback (c – a)(RVU)	22.94 ± 0.02^{b}	23.54 ± 0.37^{b}	23.67 ± 0.50^{b}	56.37 ± 3.71^{a}
Consistency (c – b) (RVU)	25.38 ± 0.05^{b}	25.75 ± 0.33^{b}	25.25 ±0.42^{b}	76.50 ± 5.83^{a}
Pasting temp. (^{o}C)	82.55 ± 1.10^{a}	81.54 ± 0.09^{b}	81.32 ± 0.03^{b}	80.73 ± 0.08^{c}
Pasting time (mins)	5.37 ± 0.04^{b}	5.37 ± 0.04^{b}	5.43 ± 0.10^{b}	5.80 ± 0.13^{a}

Means of triplicate determinations are reported and expressed on dry weight basis except for moisture. Means with different superscripts along rows are significantly different ($p < 0.05$); GSM-1: = 56.00GRF : 22.00SCF : 22.00WMF; GSM-2: = 60.50GRF: 24.00 SCF : 15.50WMF; GSM-3: = 58.25GRF : 22.38SCF : 19.37WMF; CTL-1 = 100% “Garri” flour; GRF= “Garri” flour; SCF = Soy cake flour; WMF = Whole millet flour.

These results showed that while addition soy cake and millet flours to ‘garri” flour significantly ($p < 0.05$) altered its pasting properties, the blending ratios used in the study did not produce any significant change ($p > 0.05$) in most pasting properties. Peak, trough and final viscosities of the blends were significantly ($p < 0.05$) lower than their corresponding values for 100% “garri” flour due most likely to its significantly ($p < 0.05$) higher carbohydrate content, which has been observed to have direct relationship with most pasting properties (Ocheme *et al*., 2018). These viscosity values are however much lower than their corresponding values obtained for blends of quality protein maize, soy cake and whole millet flours (Akinjayeju *et al*., 2019) and blends of wheat, pigeon pea and cassava cortex flours for functional snack (Akinjayeju *et al*., 2020). Setback viscosities of the blends also followed similar trend like other pasting properties, showing significant ($p < 0.05$) difference between the blends and 100% “garri” flour, due most probably to reduced carbohydrate content of the blends, but no significant ($p > 0.05$) among the blends.

100% “garri” flour had significantly ($p < 0.05$) lower pasting temperature (80.73^{o}C, compared to the blends (81.32 – 82.55^{o}C), due most probably to the higher content of carbohydrate in 100% “garri” flour compared to the blends. This result is in agreement with the observation of Chandra and Samsher (2013) that flour with higher starch content gelatinizes at a lower temperature than those with lower starch content. There were large positive correlations between both setback and breakdown viscosities and consistency, with $r = 1.0$ for both cases, while peak viscosity also correlated positively with water absorption capacity ($r = 1.0$), but minimum negative correlation with pasting temperature (-0.4), an indication of reduced pasting temperature of a starch paste. Positive correlation between peak viscosity and water absorption capacity has been previously reported (Zhang *et al*., 2013, Ocheme *et al*., 2018), which will produce considerable influence on the quality of the final product.

3.4. Mineral contents and mineral-mineral molar ratios

The mineral contents and mineral-mineral ratios of the flour blends and 100% “garri” flour are presented in Table 5, which showed significant difference ($p < 0.05$) between the blends and 100% “garri” flour and also among the blends for most minerals, except calcium, magnesium and to a lesser extent, zinc. Low contents of most minerals in cassava and “garri” had been previously reported [5, 40]. Addition of soy cake and whole millet flours significantly ($p < 0.05$) increased the mineral contents of the blends, especially calcium, magnesium, phosphorus and potassium. High contents of these minerals in soy and millet flours have been previously reported [14, 41]. The calcium contents, for which there was no significant difference among the blends ranged from 49.62mg/100g to 50.02g/100g for samples GSM-3 and GSM-2 respectively, with sample GSM-1 having 49.82mg/100g.

Table 5 Mineral contents (mg/100g) and mineral-mineral ratios of blends of ‘garri’, soy cake and whole millet flours

Parameter/Samples	GSM-1	GSM-2	GSM-3	CNT-1
Calcium (mg/100g)	49.88 ± 0.02^{a}	50.02 ± 0.02^{a}	49.62 ± 0.03^{a}	0.78 ± 0.04^{b}
Iron (mg/100g)	3.82 ± 0.01^{a}	3.53 ± 0.00^{c}	3.66 ± 0.01^{b}	0.22 ± 0.01^{d}
Magnesium(mg/100g)	92.26 ± 0.12^{a}	90.05 ± 0.18^{b}	90.10 ± 0.20^{b}	1.46 ± 0.01^{d}
Manganese(mg/100g)	1.97 ± 0.03^{a}	1.99 ± 0.05^{a}	1.97 ± 0.02^{a}	1.61 ± 0.01^{b}
Phosphorus(mg/100g)	224.19 ± 1.12^{a}	216.87 ± 0.84^{c}	218.27 ± 0.45^{b}	1.20 ± 0.02^{d}
Potassium (mg/100g)	629.52 ± 0.96^{b}	649.35 ± 1.24^{a}	627.15 ± 1.05^{c}	0.36 ± 0.03^{d}
Sodium (mg/100g)	47.37 ± 0.01^{b}	50.61 ± 0.04^{a}	47.82 ± 0.02^{b}	0.43 ± 0.02^{c}
Zinc (mg/100g)	2.05 ± 0.01^{a}	1.96 ± 0.00^{b}	1.96 ± 0.01^{b}	0.96 ± 0.03^{c}
Iron/Zinc	1.86 ± 0.03^{a}	1.80 ± 0.02^{b}	1.87 ± 0.01^{a}	0.23 ± 0.00^{c}
Sodium/Potassium	0.075±0.001^{b}	0.078 ± 0.001^{b}	0.076 ± 0.002^{b}	1.19 ± 0.02^{a}
Sodium/Magnesium	0.51 ± 0.01^{b}	0.56 ± 0.01^{a}	0.53 ± 0.02^{b}	0.30 ± 0.02^{c}
Calcium/Phosphorus	0.22 ± 0.00^{a}	0.23 ± 0.01^{a}	0.23 ± 0.01^{a}	0.65 ± 0.02^{b}
Calcium/Magnesium	0.54 ± 0.01^{a}	0.56 ± 0.02^{a}	0.55 ± 0.02^{a}	0.53 ± 0.01^{a}
[K:Ca + Mg)] (meq.)	1.59 ± 0.04^{b}	1.67 ± 0.02^{a}	1.61 ± 0.04^{b}	0.057 ± 003^{c}

Means of triplicate determinations are reported and expressed on dry weight basis except for moisture. Means with different superscripts along rows are significantly different ($p < 0.05$); GSM-1: = 56.00GRF : 22.00SCF : 22.00WMF; GSM-2: = 60.50GRF: 24.00 SCF : 15.50WMF; GSM-3: = 58.25GRF : 22.38SCF : 19.37WMF; CTL-1 = 100% “Garri” flour; GRF= “Garri” flour; SCF = Soy cake flour; WMF = Whole millet flour.

Potassium had the highest values for all the blends with values of 629.52, 649.35 and 627.15mg/100g for samples GSM-1, GSM-2 and GSM-3 respectively, while magnesium, iron and zinc had the least values in the blends with each having less than 2mg/100g, The low contents Zinc and Iron in the blends are in agreement with the low values of these nutrients earlier reported for soy and millet flours [14, 42], as well as for cassava [40, 43]. The high contents of many of the minerals in the blends will be beneficial to the consumers of dough meal prepared from the blends. Calcium is an important nutrient for formation of strong bone and teeth, regulation of blood pressure, blood clotting and control of body fat and weight management, while the role of magnesium in regulating muscular contraction and blood pressure has earlier been acknowledged, and its low consumption level linked with migraine, cardiovascular disease, type-2 diabetes and insulin resistance Potassium has been reported to protect the human body against arterial hypertension, and in the maintenance of osmotic balance of body fluids and regulation of muscle irritability, amongst other important functions [44].

Apart from individual minerals, mineral/mineral ratios, especially Na/K, Na/Mg, Ca/P, Ca/Mg, and Ca/K, as well as the [K/Ca + Mg)] milli-equivalent are also important, in view of their role in ensuring proper functioning of the body and protection against certain ailments. There were significant ($p<0.05$) differences among the blends for most mineral/mineral ratios, except Fe/Zn and Na/Mg for which sample GSM-2 had slightly but significantly ($p < 0.05$) lower and higher values respectively, compared to other samples. This sample also had slightly but significantly ($p < 0.05$) higher [K/Ca + Mg)] milli-equivalent. The Fe/Zn ratios of the flour blends were 1.86, 1.80 and 1.87 for samples GSM-1, GSM-2 and GSM-3 respectively, with sample GSM-2 having a slightly but significantly ($p < 0.05$) lower value than the other two samples. This is most likely due to the relatively higher proportion of “garri” flour, of low zinc and iron contents, in this sample. Na/K is considered very important because, while sodium increases the incidence of high blood pressure, potassium reduces it, which means that high Na/K ratio may be detrimental to the as this will increase the incidence of high blood pressureLow sodium and high potassium intake has been observed to help in reducing high blood pressure in many hypertensive patients. The Na/K ratios for the flour blends are 0.075, 0.078 and 0.076 for samples GSM-1, GSM-2 and GSM-3 respectively, compared to 1.19 for 100% “garri” flour. With respect to Ca/P ratio, the values for the flour samples are 0.22, 0.23 and 0.23 for samples GSM-1, GSM-2 and GSM-3 respectively. High intake of calcium relative to phosphorus is considered more beneficial since low dietary intakes of calcium compared to phosphorus, resulting in low Ca/P ratio had been linked with undesirable health conditions ranging from arterial calcification and bone loss, and in severe cases, even death [45]. Proper balance of magnesium is required for the optimum use of calcium by the body, while too much calcium relative to magnesium has been observed to result in further draining of magnesium reserves [46]. The Ca/Mg ratios for the flour blends were 0.54, 0.56 and 0.55 for samples GSM-1, GSM-2 and GSM-3 respectively. The standards for Na/K, Ca/P and Ca/Mg are < 1, ≤ 1 and between 1 and 2 respectively [47, 48]. The values obtained for these parameters in this study were all less than these maximum standards, which indicate that consumers of the dough meal prepared from the flour blends will not suffer any adverse effect on the absorption and utilization of these minerals. The values obtained for these parameters are however lower than values obtained for blends from quality protein maize, soy cake and whole millet flours by [32], except for Na/K.

The Fe/Zn ratios of the blends were 1.86, 1.80 and 1.87 for samples GSM-1, GSM-2 and GSM-3 respectively which indicates that sample GSM-2 was slightly but significantly ($p < 0.05$) lower than for other two samples. This is most probably due to the relatively higher proportion of “garri” flour, which had lower values for iron and zinc compared to other two components, in sample GSM-2. Iron and zinc are most often assessed together because they are found in similar sources, their deficiencies occur together, while the absorption one affects that of the other [49]. The maximum value of Fe/Zn ratio for which the absorption of one will not be impaired by the other is 2 [50], which is higher than values obtained for the flour samples, an indication that Zn absorption will not be impaired in the dough meal prepared from the flour blends. With respect to the [K/(Ca + Mg)] milli-equivalent, the values for the flour blends were 1.59, 1.67 and 1.61 for samples GSM-1, GSM-2 and GSM-3 respectively, compared to 0.057 for 100% “garri” flour. The slightly but significantly ($p < 0.05$) higher milli-equivalent value for sample GSM-2 could attributed its relatively higher value of potassium, due most probably due to its slightly higher proportion of soy cake flour, compared to other two samples. It has earlier been observed [51], that the ratio [K/(Ca + Mg)] ratio is considered more useful than Ca/Mg molar ratio in assessing magnesium absorption, with 2.2 taken as the maximum level at which there will be no impairment of magnesium absorption. The values obtained for the flour blends were lower than this maximum value, which indicates that consumers of dough meal that will be prepared from the flour blends will not experience acute low magnesium concentration, a condition called hypomagnesaemia.

3.5. Mineral safety index

The mineral safety index (MSI) of the flour blends for Ca, Fe, Mg, Na, Ph, and Zn, are presented in Table 6. Mineral safety index of foods is useful because it gives the possibility of a given mineral to result in its overload in the body, by comparing calculated MSI value for the mineral in a given food sample (CV) with the standard value (SV). The possibility of a mineral to result in its overload in the body is low when calculated MSI is less than its standard value [52]. These results showed that calculated MSI values for the flour blends were higher than standard values for most minerals except Ca and Na. Sample GSM-1 had the lowest calculated MSI values also for Ca and Na, compared to other two samples, most probably due its higher contents of other minerals, especially Mg and Ph (Table 5), most probably as a result of higher proportion of pearl millet which has been reported to have high contents of these minerals [14, 42]. The lower mean calculated MSI values for the samples obtained for Ca (4.16) and Na (1.94) compared to their respective standard values of 10 and 4.8, which means that potential consumers will not be exposed to risk of overloads of these minerals. On the contrary however, the mean calculated MSI values for Fe (16.39), Mg (34.05), Ph (43.95) and Zn (43.78) were higher than their standard values of 6.7, 15, 10 and 33 respectively, which showed percentage increases of 145, 127, 340 and 33% between the mean calculated MSI values and the standard values.

Table 6 Mineral safety index of selected minerals of blends of ‘garri’, soy cake and whole millet flours

Minerals/ Samples	Ca		Fe		Mg		Na		Ph		Zn	
	SV	CV	SV	CV	SV	CV	SV	CV	SV	CV	SV	CV
GSM-1	10	4.16	6.7	17.06	15	34.60	4.8	1.90	10	44.84	33	45.10
GSM-2	10	4.17	6.7	15.77	15	33.77	4.8	2.02	10	43.37	33	43.12
GSM-3	10	4.14	6.7	16.35	15	33.79	4.8	1.91	10	43.65	33	43.12
Sample mean	10	4.16	6.7	16.39	15	34.05	4.8	1.94	10	43.95	33	43.78
Sample STD		0.02		0.65		0.47		0.07		0.78		1.14
*t-test $t_{\text{-calculated}}$		$\lvert -505.76 \rvert$		25.82		70.20		$\lvert -70.77 \rvert$		75.39		16.38
*RAI		1200		15		400		1200		500		15

Table value for t-test ($t_{\text{tabulated}}$) at p = 0.05 = 4.303; GSM-1: = 56.00GRF : 22.00SCF : 22.00WMF;GSM-2: = 60.50GRF: 24.00 SCF : 15.50WMF; GSM-3: = 58.25GRF : 22.38SCF : 19.37WMF; CTL-1 = 100% “Garri” flour; GRF= “Garri” flour; SCF = Soy cake flour; WMF = Whole millet flour. SV = Standard (Table) value; CV = Calculated value; Ca = Calcium, Fe = Iron, Mg = Magnesium, Na = Sodium, Ph = Phosphorus, Zn = Zinc; STD = Sample standard deviation; *RAI = Recommended Adult Intake for each mineral (mg) (Adeyeye et al., 2016)

The results of lower calculated mean MSI values for Ca and Na, and higher values for Fe, Mg, and Zn, compared to their standard values agree with the results of [51, 54], for some fast foods commonly consumed in Nigeria and other plant products, and for blends of wheat, pigeon pea and cassava cortex flours for potential functional snack [33]. The high mean calculated MSI values, especially for Zn and Fe may be of a disadvantage to the potential consumers of the dough meal prepared from the flour blends, because high dietary intakes of certain minerals have been associated with some adverse health conditions. For instance, consumption of Zn above the daily requirements of 3 to 11mg and 3 to 8mg per day for male and female may cause its toxicity, which may lead to gastrointestinal disruptions and imbalance of Cu and Fe [55], resulting in symptoms such as nausea and vomiting, decreased immunity and reduced concentration of ‘good cholesterol’ in the body [56]. High intakes of magnesium, may lead to a condition called hyper-magnesemia, which may manifest in symptoms like excessively low blood pressure, impairment of neurological system, breathing difficulty and sometimes, coma [57]. Overload of iron in the human body results in symptoms like fatigue and high blood glucose concentration, which can also results in many other degenerative ailments. Calculated MSI for iron and zinc correlated positively (r = 0.89), which most probably corroborates previous observations of certain similarities between both nutrients such as occurrences of their deficiencies, similar causes of enhancement and impairment of their absorption as well as similar dietary sources [49]. Results of t-test showed significant ($p < 0.05$) differences between mean calculated and standard MSI values for all the minerals, including Ca and Na for which calculated MSI values were significantly ($p < 0.05$) lower than standard values, while standard MSI values were significantly ($p < 0.05$) lower that calculated MSI values.

4. Conclusion

Results obtained showed that addition of soy cake and whole millet flours to “garri” flours significantly ($p < 0.05$) altered the proximate compositions, physico-chemical and mineral profiles of the resulting blends. Addition of and increased proportions of soy cake and millet flours resulted in increases in the protein and fibre contents, as well as most functional properties of the blends, compared to 100% “garri” flour, except for bulk density and water absorption. Swelling index correlated positively with both water absorption and carbohydrate (r = 0.60 in both cases), while there was also large positive correlation between dispersibility and reconstitution index (r = 0.94). While there were significant differences in the pasting properties of the blends compare to 100% “garri” flour, addition of soy cake and millet flours did not produce any significant difference ($p > 0.05$) among the blends, which indicated that addition of these flours had no significant effects ($p > 0.05$) on the pasting properties of the flour blends, except pasting temperature for which sample GSM-1 had slightly but significantly ($p < 0.05$) higher value (82.55°C), compared to 81.54 and 81.32°C for other two samples. Peak viscosity had positive correlation with water absorption (r = 1.0), but small negative correlation with pasting temperature (r = -0.4), setback viscosity had large positive correlations between both breakdown and consistency (r = 1.0) in both cases. Mineral contents increased significantly ($p < 0.05$) in the blends with the addition of soy cake and millet flours, which will be beneficial to the potential consumers. However, there was no significant ($p > 0.05$) difference among the flour blends for most mineral-mineral ratios, which indicated that addition and varying proportions of soy cake and millet flour did produce any significant effect on the mineral-mineral ratios. Calculated MSI values for the flour blends were higher than standard values for the selected minerals in all flour blends, except for Ca and Na, which shows that there will be no risk of overload of these minerals in consumers, unlike for Fe, Mg, ph and Zn, which had higher average calculated MSI values compared to standard values. There were significant ($p < 0.05$) differences among the flour blends in the calculated MSI values and standard values. There will be the need to evaluate other properties of the blends, including anti-nutritional, anti-oxidant and glycaemic, and the sensory properties of dumplings prepared from them, which may be affected by some of the parameters measured in this study. These will be the focus of subsequent studies.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest whatsoever, before, during and after the collection of data, compilation of results and writing of the paper.

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