Effect of the Addition of Pearl Millet Flour Subjected to Different Processing on the Antioxidants, Nutritional, Pasting Characteristics and Cookies Quality of Rice-Based Composite Flour

Abstract

Composite flour was developed from rice, soybean, tigernut and millet composite flours; with the millet subjected to different processing techniques such as debranning, fermentation and malting in other to determine the effect of processing methods on the quality of the flour. The proximate composition, functional properties and pasting characteristics, of the composite flour were evaluated. Cookies were produced from the best blend from each of the malted, fermented and debranned millet composite flours. The results showed that flour blend with malted millet had the highest ash and fiber contents. Composite flour consisting fermented millet had the highest protein content, functional properties and pasting characteristics. In terms of pasting properties, composite flour with fermented millet was the best followed by flour blend with malted millet. Cookies produced from the flour blend with fermented millet had the highest overall acceptability. The result showed that the quality of flour and biscuits were improved by the processing techniques and that the composite flour were good raw materials that could produce quality composite flour and acceptable cookies.

Keywords: Debranning; Cookies; Composite flour; Fermentation; Pasting; Proximate; Malting

Research Article

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Introduction

Biscuit is a popular bakery product worldwide. Biscuit is widely accepted by all age group due to its longer shelf life, better taste and its position as snacks; it is also considered as a good product for protein fortification and other nutritional improvement [1]. Due to competition in the market and increase demand for healthy, natural, and functional products, attempt are been made to improve the nutritive value of cookies and functionality by modifying their nutritive [2]. Composite flour are being developed consisting as a substitute to primarily wheat flour in the production of baked products [3,4]. Composite flours consisting cereals with legumes, fibre sources and hydrocolloids which can serve as viable alternatives to wheat flour have been researched into. [5-9]. Major advantages of these composite flours are their enhanced nutritional (protein, antioxidants, fibre, minerals) in addition to being gluten-free [6,7]. In addition, composite flours enhance the utilization of local and underutilized local and inexpensive food raw materials in the production of bakery products. Millets *(Penisetum glaucum)* are groups of small seeded species of cereal crops or grains, widely grown around the world for food and staples [10]. Millet could also be malted and milled into flour or brewed into various drinks and can be as well dehulled and milled into flour. Millet is predominantly starchy and the bran layer of millet is good sources of b-complex vitamins [11]. It also serves as a source of antioxidant in our diets [11].

Rice *(Oritza sativa)* is a principal leading food crop of the world and a staple food of over approximately half of the world's population. Rice flour is considerably lower in protein content compared with wheat flour and does not contain gluten, hence, it is good source of flour for people who are gluten intolerant [12]. Extruded snack with high nutritional and antioxidant properties have been developed from rice-based composite flour [3].

Soybean *(Glycine max)* is a remarkable source of protein for both animals and human consumption and is also a leading source of edible oils and fats [13]. Soybean is the only source that contains all the amino acids, it is used in the production of bread, cookies and other composite flour has been reported [14-16]. Soybean is cheap and this with its advantage of high nutrient makes it widely accepted and used for various forms of meals and snacks.

Tiger nut (*Cyperusesculentus)* is an underutilized crop reported to be high in dietary fibre content which could be effective in the treatment and prevention of many disease including colon cancer, coronary heart diseases, heart diseases, obesity and gastro intestinal disorder [17]. Tiger nut flour has been demonstrated to be a rich source of quality oil, vitamin E and contains some useful minerals such as iron and calcium which are essential for body growth and development [18]. Due to its high amino acids contents, tiger nut has inherent nutritional and therapeutic advantage which could serve as a good alternative to cassava in baking industry.

This study therefore focus on making a quality and functional cookies from composite flour comprising of millet, rice, soybean, and tiger nut, using carboxyl methyl cellulose as a binder. The millet was subjected various processing techniques (debranning, fermentation and malting) in order to ascertain the effect of the processing techniques on the nutritional and dough properties.

Materials and Methods

Materials

The millet, rice, soybean seed and tigernut seed were purchased from Oba market, Akure, Ondo state Nigeria.

Methods

Pearl millet debranning: The pearl millet grains were cleaned to removed dirt, sand and other extraneous material by winnowing. The cleaned grain were then soaked in water for 18 h to soften the seed coat and to allow easy removal of the bran containing phytic compounds. The debranning was manually carried out and the debranned grain oven-dried until constant moisture content was obtained. It was later milled in an attrition mill, sieved and the pearl millet flour obtained stored in sealed polythene bags at room temperature for analysis.

Pearl millet fermentation: The pearl millet was fermented using the method of Lei and Jacobsen [19]. The pearl millet was sorted to remove extraneous material, thoroughly washed in clean water, soaked soaked in water for 48 h to ferment, the fermented millet was oven-dried to constant moisture, milled and sieved and stored in sealed polythene bag for further processing.

Pearl millet malting: The malting of the pearl millet was carried out using the method of [20]. The malting process comprises of three main stages: steeping, germination and drying. Pearl millet was sorted and washed five times to remove foreign materials. The grains was put in a large nylon bag and was spin dried to remove excess surface held water, it was then tied at the mouth, the grain in the nylon bags was steeped in static water at room temperature, with a cycle of 2 h wet and 2 h dry air-rest, for 8 h. During the air-rests, the grain was held in still air at 20-22°C. After steeping, the grain was spin-dried (30 s at 300 x g) and reweighed. The grain was then left in the nylon bag for germination for five days at room temperature. The germinated grain was oven-dried, milled and sieved and stored in sealed polythene bag for further processing.

Preparation of rice flour: Rice flour was prepared using the method adopted by [3]. The rice grains (5Kg) were sorted, washed, oven-dried and milled into flour.

Preparation of tigernut flour: The method of Adeyemi [21] was used. Dry tigernuts were sorted to remove unwanted materials, thoroughly washed, oven-dried at 60°C for 24 h. The dried nuts were milled and sieved to obtain very fine flour; the resultant flour was packed and sealed in polythene bags for further analyses.

Blends preparation: Fifteen blends were prepared by mixing rimillet, soy and tigernut flours with 0.2 g carboxyl methyl cellulose (CMC) binder (Table 1). Samples were labelled A, B and C for composite flours comprising malted, fermented and debranned millet flours respectively.

Table 1: Blend formulation for the composite flour.

*Samples	Rice Flour	Malted Millet Flour	Soybean Flour	Tigernut Flour	C.M.C
A1	100	0	5	5	0.2
A2	90	10	5	5	0.2
A3	80	20	5	5	0.2
A4	70	30	5	5	0.2
A5	60	40	5	5	0.2
Fermented Millet Flour					
B1	100	0	5	5	0.2
B2	90	10	5	5	0.2
B3	80	20	5	5	0.2
B4	70	30	5	5	0.2
B5	60	40	5	5	0.2
De-Branned Millet Flour					
C1	100	0	5	5	0.2
C2	90	10	5	5	0.2
C3	80	20	5	5	0.2
C4	70	30	5	5	0.2
C5	60	40	5	5	0.2

*A1, B1, C1 =100:0:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A2, B2, C2 = 90:10:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A3, B3, C3 = 80:20:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A4, B4, C4 = 70:30:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A5, B5, C5 = 60:40:5:5:0.2 (rice: millet: soy: tigernut: CMC)

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Biscuit production: Biscuits were produced from the blend formulations using the two stage creaming-up method. The baking formula is as described by [22]. All ingredients except flour and sodium bicarbonate were added with continued mixing. The dough was then placed on a cutting board, rolled out until uniform thickness and textures were obtained. Biscuit cutter was used to cut the sheet of rolled dough into desired shapes and sizes. The shaped dough pieces were then baked at about 220 ˚C for 15 min, allowed to cool, packed and stored [14]. The flow chart in fig 3.6 shows the procedure for biscuit production.

Sensory evaluation: The method used by Awolu et al. [6] was adopted. Sensory evaluations of the biscuit samples were evaluated for taste, appearance, aroma, texture, and overall acceptability by a panel of ten members using a 9-point Hedonic scale. The rating of the samples ranged from 1 (Dislike extremely) to 9 (Like extremely) conducted by 10 panelists**.**

Determination of proximate composition of the composite flour: Moisture, total ash, crude fat (Solvent extraction) and crude fibre contents of the composite flours were determined using the standard methods of Association of Official Analytical Chemists [23]. The crude protein content was determined by the micro Kjeldahl nitrogen method and the nitrogen content was converted to protein using a 6.25 conversion factor. Carbohydrate content was determined by difference.

Determination of water and oil absorption capacity of the composite flour: The water and oil absorption capacity of the composite flours were determined as described by Fagbemi et al. [24] adapted from Sathe et al. [25]. For water absorption capacity, 10 ml of water was added to 1.0 g of the flour sample in a beaker and stirred using magnetic stirrer for 5 min. The resulting suspension was centrifuged for 30 min at 2,500 × g. The supernatant was decanted and the volume measured. The volume of water and oil absorbed was calculated as the difference between the initial volume of water/oil used and the final volume of the decanted supernatant. The result was expressed in percentages.

Determination of bulk density and least gelation capacity: The bulk density was determined as described by Fagbemi et al. [24] some quantity of the flour sample was transferred to a pre-weighed measuring cylinder (W1) and the new weight (W2) was recorded. The volume occupied by the flour in the measuring cylinder was recorded. The bulk density was expressed by the Equation (1)

$$BulkDensity\, g/ml = \frac{W2 - W1}{Volume of sample} \quad (1)$$

The least gelation concentration (LGC) was determined using the procedure of Coffman and Garcia [26]. Flour sample suspensions of 2–20 % (w/v) were prepared in distilled water. An aliquot of 10 ml from each sample suspension was transferred to different test tubes which were heated in a gentle boiling water bath for 60 min. The test tubes were then cooled rapidly in a water bath for 2 h, followed by further cooling in 4 °C water bath. The LGC was taken as the concentration when the samples in the test tubes did not fall or slip when inverted.

Determination of swelling power and solubility index: Swelling power and solubility index were determined using the procedure of Takashi and Sieb [27]. Briefly Sample (1 g) was weighed into 50 ml centrifuge tube and 50 ml of distilled water was added and mixed gently. The slurry was heated in a water bath at 50, 60, 75, 90 °C, respectively for 15 min. During heating, the slurry was stirred gently to prevent clumping of the starch. After 15 min, the tubes containing the paste were centrifuged at 3000 x g for 10 min using SPECTRA U.K. (Merlin 503) centrifuge. The supernatant was decanted immediately and the weight of the sediment was taken and recorded. The moisture content of the gel was thereafter determined to get the dry matter content of the gel. Swelling power was determined using Eq. (2)

$$SwellingPower\ (g/g) = \frac{Weight\ of\ mass sediment}{Weight\ of\ drymatteringel} \quad (2)$$

Determination of dispersibility: Dispersibility was determined by the method described by Kulkarni et al. [28]. The flour (10g) was suspended in 100 ml measuring cylinder and distilled water was added to reach a volume of 100 ml. The set up was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility.

Determination of pasting properties: Pasting properties of flour was characterized using Rapid Visco Analyser (RVA) Model 3C, Newport Scientific PTY Ltd., Sydney as described by Sanni et al. [29].

Determination of minerals: The method described by AOAC (2000) was used. About 2 g of the sample was placed in the crucibles, ashed in a muffle furnace at 550 °C for 5 h and then transferred into the desiccators to cool. The ashed sample was digested with 3cm^3 of 3M HCl and made up to the mark in a 100 cm^3 standard flask with 0.36 M HCl. Magnesium, calcium and zinc were determined using atomic absorption spectrophotometer (Buck scientific 210 VGP) while sodium and potassium were determined using flame photometer.

Determination of antioxidant properties

Determination of total phenol: The total phenol content of the composite flour was determined by the method of Singleton et al. [30]. About 0.2 ml of the flour extract was mix with 2.5 ml of 10% Folin-Ciocalteau's reagent and 2 ml Sodium carbonate (7.5%). The reaction mixture was subsequently incubated at 45 °C for 40 min, and the absorbance was measure at 700 nm in the spectrophotometer. The total phenolic compound in garlic acid equivalent (GAE) was calculated.

Determination of ferric reducing antioxidant power (FRAP) property: The reducing property of the composite flour was determined by the modified method of Oyaizu [31]. Flour extract (0.25ml) was mixed with 0.25 ml of 200 mM of Sodium phosphate buffer pH 6.6 and 0.25 ml of 1% KFC. The mixture was incubated at 50oC for 20min, thereafter 0.25ml of 10% TCA was also added and centrifuge at 2000rpm for 10min, 1ml of the supernatant was mixed with1ml of distilled water and 0.1% of $FeCl_3$ and the absorbance was measure at 700nm and ferric reducing antioxidant property was calculated.

Determination of DPPH free radical scavenging ability: The free radical scavenging ability of the extract against DPPH (1, 1-

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diphenyl-2-picryhydrazyl) Using Singleton et al. [30] method. The flour extract (1 ml) was mixed with 1ml of the 0.4 mM methanolic solution of the DPPH. The mixture was left in the dark for 30 min and the absorbance measured at 516 nm.

Determination of oxalate: Oxalate determination was determine by soaking 1g of the sample in 75ml of 1.5N H_2SO_4 for 1hr and then filter through a No 1 Whatman filter paper. The filtrate (25 ml) will be placed inside a conical flask and titrated hot (80-90 °C) against 0.1M $KMnO_4$ until a faint pink colour that persisted for 15s [32].

Statistical analysis: The data were analysed using SPSS version 16.0. The mean and standard error of means (SEM) of the triplicate analyses of the samples were calculated. The analysis of variance (ANOVA) was performed to determine significant differences between the means, while the means were separated using the Duncan New Multiple Range tests (DNMR).

Results and Discussion

Sensory evaluation of cookies

The results of the sensory evaluation of the cookies are shown in Table 2. The overall acceptability ranged from 6.7 to 7.6. The analysis of variance showed that the sample with fermented millet (B4) had overall best acceptability, though not significant different (p<0.05) from sample with debranned millet (C5). In addition, sample B4 had the best colour, taste, appearance, texture (Table 2).

Table 2: Sensory evaluation of the biscuit produced from selected samples.

*Sample	Colour	Flavour	Taste	Appearance	Texture	Overall Acceptability
A4	6.3±1.01a	6±1.4a	6.5±1.58a	6.1±0.88a	6.4±1.71a	6.7±0.94a
B4	7.5±0.85b	6.21±1.5a	7.1±1.6a	7.4±1.08b	7.11±1.10c	7.6±1.10b
C5	6.3±0.48a	6.6±0.96a	7.3±1.16a	7.2±1.23b	6.6±0.51b	7.6±0.52b

*A4 = 70:30:5:5:0.2 (rice: malted millet: soy: tigernut: CMC)

*B4 = 70:30:5:5:0.2 (rice: fermented millet: soy: tigernut: CMC)

*C5 = 60:40:5:5:0.2 (rice: debranned millet: soy: tigernut: CMC)

Proximate analyses

The results of the proximate analyses are shown in Table 3. The moisture content is generally low, as required for flours. There is no significance differences in all the values obtained for the various blends and for various processing (malting, fermenting and debranning). Altogether the values obtained are in range of the values obtained by Reihaneh and Jamuna [33]. Low moisture content is important in cookies production as it limit the water available for microbial activity and thereby resulting into a stable product with longer shelf life.

The ash content ranged from 1.62 to 1.78 for samples A; 1.62 to 1.63 for samples B and 1.63 to 1.65 for samples C. All the processes (malting, fermentation and debranning) reduce the ash contents significantly. Ash is indicative of the amount of minerals contained in any food sample.

The fat contents of the samples were above average. Fat, in addition to carbohydrate are sources of energy in food. Higher fat content is an indication of more total energies available [34]. Addition of millet significantly increases the fat contents. Debranning had least reduction on fats, followed by malting and fermentation. Samples A5, B4 and C5 were significantly higher (p<0.05) in fat than other samples. In addition, the inclusion of soybean flour and tigernut flour to millet and rice flour may further increase the fat content [35,36].

Protein content in the flour samples ranged from 10.08 to 14.78. The high protein values of composite flour may be attributed to addition effect of soybean flour. Fermented millet flour had the highest protein value followed by malting. Debranning had pronounced reduction on the protein. It had been shown that fermentation process improves the nutritional value and reduces the risk of food borne illness, hence, beneficial health effects.

Carbohydrate contents are generally high. This will have good energy effects. Crude fibre reduces with malting, fermentation and debranning. Major health benefits associated with increased intake of dietary fibre includes reduce risk of heart diseases, diabetes, obesity and some forms of cancer [37] (Table 3).

Functional properties of the composite flour

The result of the functional properties is shown in (Tables 4a & b). Bulk density ranged from (0.71 g/ml) to (0.83 g/ml). Bulk density values decreased gradually with the flour blends containing malted and de-branned millet flour and increased slightly in the flour blends containing fermented millets with increase. The density of processed products dictate the characteristics of its container or package; product density influences the amount and strength of packaging material, texture or mouth feel [38]. Values obtained from this study were comparable with the values reported by Okaka and Potter [39] for cowpea (0.60 g/ml) and also for pearl millet as reported by Singh et al. [40]. The decrease in bulk density of composite flour would be an advantage in the preparation of infant foods. Fermentation has been reported as a useful and traditional method for the preparation of low bulk weaning foods.

The swelling capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations. As per literature, the flour of parboiled rice has more swelling capacity as compared to raw rice. The values of swelling capacity obtained in this study ranged from 21.28 to 30.7 at 50 °C, 21.13 to 33.3 at 60 °C, 27.56 to 45.5 at 75 °C, 31.4 to 39.9 at 90 °C. Malting (sample A30 had the highest swelling power.

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Table 3: Proximate composition of the flour blends.

*Samples	Moisture (%)	Ash (%)	Crude Fibre (%)	Crude Protein (%)	Fat (%)	Carbohydrate (%)
A1	8.97±0.88	1.78±0.03c	2.43±1.05d	14.58±0.09f	4.9±0.1ab	69.89±1.52b
A2	7.35±0.73	1.78±0.02c	1.72±0.03abc	13.47±0.00b	5.40±0.07c	70.25±3.00b
A3	7.62±0.67	1.64±0.01ab	1.8±0.15abc	13.47±0.18b	5.8±0.05d	69.24±3.00b
A4	6.93±0.39	1.65±0.01b	1.97±0.03cd	13.82±0.00c	6.33±0.08f	69.59±1.53b
A5	8.23±0.15	1.62±0.01a	1.9±0.00bc	14.08±0.27d	7.48±0.41h	66.86±153ab
B1	8.97±0.88	1.78±0.03c	2.43±1.05d	14.58±0.09f	4.9±0.1ab	67.83±3.00ab
B2	8.18±0.55	1.63±0.02ab	1.90±0.09bc	14.28±0.10g	5.9±0.15de	67.60±1.53ab
B3	8.26±0.70	1.63±0.02ab	1.82±0.03abc	14.78±0.11h	6.36±0.05f	66.62±3.00ab
B4	7.22±0.15	1.62±0.01a	1.74±0.09abc	14.78±0.12h	7.01±0.17g	69.78±3.00b
B5	8.95±2.57	1.63±0.02ab	1.62±0.03bc	14.00±0.13i	6.22±0.13i	63.8±3.00a
C1	8.97±0.88	1.78±0.03c	2.43±1.05d	14.58±0.09f	4.63±0.12a	70.86±3.00b
C2	8.23±0.10	1.65±0.01ab	1.33±0.03a	10.08±0.14a	5.00±0.13b	70.38±3.00b
C3	8.23±0.10	1.64±0.02ab	1.4±0.05ab	10.73±0.16bc	6.1±0.21ef	70.17±1.53b
C4	8.23±0.10	1.65±0.01ab	1.35±0.05ab	11.75±0.17bc	6.78±0.04g	69.53±1.53b
C5	8.23±0.10	1.63±0.01ab	1.35±0.05ab	11.08±0.18d	7.71±0.33h	66.92ab

*A1, B1, C1 =100:0:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A2, B2, C2 = 90:10:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A3, B3, C3 = 80:20:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A4, B4, C4 = 70:30:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A5, B5, C5 = 60:40:5:5:0.2 (rice: millet: soy: tigernut: CMC)

Table 4a: Functional Properties of the composite flour blend.

*Sample	Bulk Density	Swelling Power				Least Gelation
		50 °C	60 °C	75 °C	90 °C	
A1	0.75±0.01b	22.4±0.00d	27.4±0.1c	43.7±0.00h	31.6±0.10a	1.2±0.00a
A2	0.75±0.00b	22.06±0.06c	29.7±0.10f	44.86±0.5i	31.56±0.06a	1.4±0.00ab
A3	0.78±0.01d	20.36±0.06a	23.03±2.50c	45.5±0.5j	32.66±0.15b	1.2±0.00a
A4	0.82±0.01f	21.28±0.00b	26.36±0.15e	36.32±0.01e	35.5±0.10e	1.4±0.00bc
A5	0.78±0.01d	22.06±0.06c	27.46±0.45e	41.26±0.06f	34.4±0.34d	1.2±0.00a
B1	0.83±0.01f	22.46±0.15d	30.4±0.10f	33.06±0.06d	31.4±0.00a	1.6±0.00cd
B2	0.8±0.01e	22.56±0.00d	30.13±0.12f	32.1±0.10c	36.16±0.15e	1.4±0.00bc
B3	0.75±0.01b	30.6±0.10g	19.33±0.29a	36.4±0.10f	37.06±0.6h	1.6±0.00cd
B4	0.71±0.01a	22.81±0.15d	30.6±0.00f	36.32±0.01f	37.91±0.01j	1.4±0.00bc
B5	0.79±0.00de	30.7±0.00g	23.4±0.00cd	36.6±0.01f	36.7±0.2g	1.6±0.00cd
C1	0.75±0.01b	24.66±0.0f	33.3±0.10g	29.6±0.52b	35.33±0.15e	2.2±0.00ef
C2	0.76±0.02c	23.86±0.06e	24.36±0.15cd	29.7±0.10b	39.1±0.00k	1.6±0.00cd
C3	0.78±0.01d	31.7±0.00h	32.7±0.00g	27.56v0.58a	39.3±0.00k	2.00±0.00de
C4	0.75±0.01b	30.5±0.5g	21.13±0.12b	34.73±0.21e	33.63±0.15c	2±0.00de
C5	0.75±0.00b	22±0.00c	21.85±0.01b	34.4±0.10e	37.66±0.01i	1.8±0.00ds

*A1, B1, C1 =100:0:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A2, B2, C2 = 90:10:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A3, B3, C3 = 80:20:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A4, B4, C4 = 70:30:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A5, B5, C5 = 60:40:5:5:0.2 (rice: millet: soy: tigernut: CMC)

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Table 4b: Functional Properties of composite flour (Continued).

*Sample	OAC	WAC	Dispersability
A1	1.70±0.01a	2.16±0.05c	60±0.00a
A2	1.9±0.00c	2.20±0.00b	68±0.00d
A3	1.8±0.00b	2.16±0.05b	66±1.0d
A4	1.81±0.01b	2.06±0.05ab	70±0.00ef
A5	1.8±0.10d	2.03±0.05ab	72±1.0hi
B1	1.70±0.01a	2.16±0.05c	60±0.00a
B2	1.80±0.10b	2.06±0.05ab	65±0.00cd
B3	1.90±0.01c	2.23±0.03b	70.66±0.58d
B4	2.1±0.00e	2.13±0.05b	72.5±1.53i
B5	1.8±0.00b	2.1±0.00ab	66.33±1.53d
C1	1.70±0.01a	2.16±0.05c	60±0.00a
C2	2.13±0.12e	1.53±1.15a	64±1.00c
C3	2±0.00e	1.86±0.06ab	68±0.00e
C4	1.8±0.1b	2.16±0.06a	61.66±1.53b
C5	2.1±0.00e	2.00±0.00ab	65.5±0.71d

*A1, B1, C1 =100:0:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A2, B2, C2 = 90:10:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A3, B3, C3 = 80:20:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A4, B4, C4 = 70:30:5:5:0.2 (rice: millet: soy: tigernut: CMC)

*A5, B5, C5 = 60:40:5:5:0.2 (rice: millet: soy: tigernut: CMC)

The temperature at which gelatinization of starch takes place is known as the gelatinization temperature [31]. The least gelation value obtained ranges from 1.2 to 2.2%, the highest gelation value was observed for C1 which is the flour sample with the debranned millet flour and the lowest value obtained was in the categories of flour samples containing malted millet flour. The result falls within the range of the values obtained by Chandra and Samsher [42] who reported the gelatinization of some flours such as wheat flour 1.94, rice flour 0.98 and potato flour 2.48. Due to higher starch content some flour gelatinize quickly while some will take more time due to lower starch content.

Oil absorption capacity was highest in composite flour comprising debranned millet, followed by the blends with fermented millet. OAC increases as degree of substitution of millet blends increases. Overall, oil absorption capacity values ranged from 1.70 to 2. The oil-absorption capacity of these flour blends suggests that it is not useful for baking alone but would also be useful in formulation of foods where oil absorption property is an important consideration. Most cereals contained good oil absorption capacity as reported for sorghum (7.03 ml/g), pearl millet (6.7 ml/g) and maize (6.9 m/g)] by Singh et al. [40]. These results are in agreement with Elkhalifa et al. [43] who reported about 7 % increase in oil absorption capacity after 8 h of fermentation of sorghum flour. Awolu et al. [3] reported OAC ranging from 1.75 to 2.21 for rice, cassava and kersting's groundnut composite flour. Variation in oil absorption capacity might be due to the different proportion of the protein molecules present in each of the samples.

The water absorption capacity ranged from 1.53 to 2.23. WAC is highest in blends with fermented millet followed by blend with malted millet. There are significant differences between the blends. The result obtained is similar to that obtained by Awolu et al. [3] for rice, cassava and kersting's groundnut composite flour. The ability of flour to absorb water was reported to have a significant correlation with its starch content [44]. High WAC assures product cohesiveness due to loose association of amylose in starch granules and weakness associative force [45]. Water absorption capacity gives an indication of the amount of water available for gelatinization. Lower absorption capacity is desirable for making thinner gruels.

The dispersibility of the flour blends ranged from 60 to 70%. Malted and fermented millet flour blends had the highest dispersibility while debranned millet flour blends the least. Malomo Olu et al. [46] discovered that 100% yam flour had higher dispersibility than yam flour enriched with soy; 100% yam flour had higher WAC. Higher dispersibility indicated flour that is easily reconstituted [46]. The high values of dispersibility showed that the blends will be easily reconstituted to give fine consistency dough during mixing [47] (Table 4a & b).

Best blends

The three best blends chosen; one for each of malted, fermented and debranned millet, based on the results of the proximate and functional analyses were samples A4, B4 and C5.

Pasting characteristics

The results of the pasting properties are shown in Table 5. The peak viscosity ranged from 133 to 184 RVU. Peak viscosity indicates the maximum swelling capacity of starch granules [48]. It also indicates the water binding capacity of the starch granules. Flour blend with fermented millet (B4) had the highest peak viscosity, followed by blend with malted millet (A4). The trough was highest in fermented millet blend, followed by debranned millet blend.

Breakdown viscosity was highest in blend with malted millet, followed by blend with fermented millet. Breakdown measures the ease with which the swollen granules can disintegrate [49]. It has been explained that the higher the breakdown, the lower the ability of the starch to withstand heating and shear stress during cooking [50], hence, blend with debranned millet had highest stability.

The final viscosity is the ability of the starch to form a viscous paste [51]. A reduced final viscosity indicated a reduced ability of sample to form viscous paste. All the samples showed reduction in final viscosity. A4 showed 34% reduction, B4 showed 7.4% reduction while C5 showed 1.8% reduction.

Set back as be described as a measure of recrystallization of gelatinized starch after cooling [51]. It has been shown that high amylose content resulted in increased tendencies of syneresis and retrogradation [52] Chang and Liu. Sample B4 had the highest setback, followed by A4 and then C5.

Table 5: Pasting properties of the composite flour samples.

*Sample	Peak	Trough	Breakdown	Final Visc	Setback	Peak Time	Pasting Temp (°C)
	(RVU)	(RVU)	(RVU)	(RVU)	(RVU)		
A4	184.08	83.67	100.42	121.58	37.92	6.33	92.35
B4	206.75	128.58	78.17	191.25	62.67	5.75	91.45
C5	133.17	94.83	38.33	130.83	36	6.95	92.42

*A4 = 70:30:5:5:0.2 (rice: malted millet: soy: tigernut: CMC)

*B4 = 70:30:5:5:0.2 (rice: fermented millet: soy: tigernut: CMC)

*C5 = 60:40:5:5:0.2 (rice: debranned millet: soy: tigernut: CMC)

The pasting temperature ranged from 91.45 to 92.45. Sample C5 had the highest pasting temperature, followed by A4 and then B4. Pasting temperature is an indication of the minimum temperature required to cook the flour [49]. Overall, sample B4 showed highest dough swelling capacity while sample C5 showed highest dough stability

Mineral analysis

The mineral contents of the selected flour blends are shown in Table 6. Sample B4 had the highest value of potassium, zinc and sodium, sample A4 was high in calcium and magnesium. Although minerals are micronutrients, and are required in a minute amount in the body, they are needed for specific immune functions and their absence can result in certain deficiency diseases.

Antioxidant and antinutrition properties of samples

The results of antioxidant and antinutrition properties are presented in Table 7. The DPPH values obtained for the samples were high as a result of the presence of pearl millet in the flour samples. Pearl millet had been shown to possess high antioxidant properties [11]. Antioxidants are reducing agents [53] and counter the accumulation of free radicals in the body. Oboh & Rocha [54] had demonstrated reducing power of flour samples.

Table 6: Minerals content of selected samples (ppm).

Sample	Mg	Ca	K	Na	Zn
A4	1.17±0.3c	2.4±0.10c	42.21±1.43a	13.6±0.1b	0.45±0.01b
B4	0.8±0.10b	2.1±0.10b	83.45±0.05c	16.7±0.2c	0.56±0.01c
C5	0.7±0.10a	1.7±0.10a	55.3±0.8b	12.20±0.01a	0.41±0.01a

Table 7: Antioxidant and antinutrition properties of some selected samples.

Sample	Antioxidants			Antinutrition
	Frap	Phenol	DPPH	Oxalate
A4	3.24±0.19b	0.98±0.03b	60.45±0.93c.	0.27±0.0a
B4	3.69±0.11c	2.47±0.39c	52.23±0.22b.	0.58±0.06b
C5	2.41±0.21a	0.92±0.34a	10.86±.0.14a	0.81±0.00c

Phenols and phenolic compounds have been reported to possess significant antioxidant activities [55]. The total phenolic content of the sample containing fermented millets (B4) is higher than what was reported by Oboh et al. [56] for fermented African locust bean. This indicates that regular consumption of fermented pearl millet may serve as a dietary source of antioxidants. Also, the values obtained were higher than what was obtained for *Carica papaya* and *Cajanus cajan* by Imaga et al. [57]. These higher values agree with report of Vattem et al, [58] that fermentation of cranberry pomace improved phenolic content and antioxidant activity.

FRAP assay measures the reducing potential of an antioxidant reacting with a ferric tripyridyltriazine (Fe^{3+}-TPTZ) complex and producing coloured ferrous tripyridyltriazine (Fe^{2+}-TPTZ) [59]. Generally, the reducing properties are associated with the presence of compounds which exert their action by breaking the free radical chain by donating a hydrogen atom [60]. According to Benzie and Strain [59], the reduction of Fe^{3+}-TPTZ complex to blue-coloured Fe^{2+}-TPTZ occurs at low pH. FRAP values of sample B4 were significantly higher than other samples which A4 and C5.

Oxalates limit the availability of calcium in the body, being calcium binders. The results of the antinutritional evaluation of the selected flour samples showed that it ranged from 0.27 to 0.81. The oxalate level of sample A4 was the lowest which indicated that the malting had ability to reduce oxalate. It had been found that soaking reduces oxalate contents of samples Njoki. The oxalate levels in samples B4 and C5 are safe for human consumption.

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Conclusion

The effect of addition of pearl millet subjected to different processing techniques on the composite flour comprising rice, soybeans and tigernut on the proximate composition, functional and pasting properties evaluated showed that the addition of fermented pearl millet flour was the best compared to debranned and malted pearl millet flours; fermentation increases the protein contents of the composite flours; malting, fermentation and debranning increases the functional properties. In general the all the composite flours had good and acceptable nutritional and flour quality which could be used in producing acceptable cookies.

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Conflict of Interest

Authors declare there are no conflicts of interest.

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