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Physicochemical, rheological, and sensory characteristics of bread processed from a blend of maize and wheat flour

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ABSTRACT

Study objectives: This study aimed to investigate the physicochemical, rheological, and sensory characteristics of bread processed from a blend of maize and wheat.

Methods: Maize flour was used to replace 25, 50, 75, and 100% of wheat flour used in bread processing.

Results: The functional properties of maize-wheat flour, such as water absorption capacity, oil absorption capacity, and bulk density, were increased with an increase in the incorporation of wheat flour, except that the foaming capacity was found to be decreased with the increase of maize flour. The properties of paste (wet and dry gluten, and gluten index) of maize-wheat flour compared with wheat flour (control) were found to be lower ($p<0.05$). The same trend was found to be in the least gelation capacity result and decreased with the increase of maize flour (12.50, 7.80, 4.75, and 1.90% for maize-wheat 25, 50, 75, and 100%, respectively), compared with the control (16.0%). The proximate composition of maize-wheat flour bread was determined. The crude protein and moisture content of maize-wheat bread were found to be decreased with the increase in maize flour; the opposite was found in ash, fiber, crude fat, and total carbohydrates. Sensory evaluation results indicated that overall acceptability and other attributes for maize-wheat flour bread were awarded the highest score for the control, followed by 25%, as compared to the other blends, which recorded low scores, by panelists. The results indicated that both loaf weight and volume decreased with the increase of maize flour compared with the control, which recorded higher values.

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There was no significant difference (p<0.05) in the specific volume values between the maize-wheat bread blend at 25% and the control.
Conclusion: Maize-wheat flour may be used in composite flour bread preparation at the level of 25% or less with acceptable physical and sensory attributes.

Key words: physicochemical properties, rheological and sensory characteristics, bread, maize, wheat flour

Introduction

Bread is one of the cereal products. It is a baked product made from wheat cereal products that have constituted the major component of the human diet throughout the world (1). It is the staple food of the Middle East and in many countries of the world. It is usually made from wheat flour dough that is cultured with yeast, allowed to rise, and finally baked in an oven (2). It is prepared from a dough of flour and water, usually by baking. Throughout recorded history, it has been a prominent food in large parts of the world (3). Wheat is a unique cereal that is suitable for the preparation of a wide diversity of leavened bread that meet consumer demands and requirements worldwide (1). Among baked products, bread has been a staple food for many civilizations. Even today, bread and cereal-based products constitute the base of the food pyramid, and their consumption is recommended in all dietary guidelines (2). Wheat flour of both hard and soft wheat classes has been the major ingredient of leavened bread for many years because of its functional proteins (4). Also made from the flour of other wheat species and non-wheat cereals, including rye, barley, maize (corn), oats, sorghum, millet, and rice, have been used to make bread, but, except for rye, usually in combination with wheat flour, as they have less gluten (5). Maize is one species of crop cereal providing the main energy ingredient. The traditional maize, like other cereals, also provides proteins, lipids, and a little water (6). Maize has also diuretic properties when taken as a tea and is a component in certain oils, corn oil, and syrup. One of the nutritional benefits of maize comes from its rich carbohydrate that is derived from its abundant starch (7). Maize is also very rich in thiamine or vitamin B1, which is necessary for the brain to absorb glucose and transform that food into energy. Biotin or Vitamin B7 gave nutritional benefits to maize since the deficiency of this vitamin in the body affects the state of the skin and hair (8). The nutritional benefits of maize are also determined by its vitamin A, which functions as an antioxidant in preventing diseases such as cancer (9). In Sudan, the consumption of wheat bread is increasing in both rural and urban areas because of changing tastes, convenience, and consumer subsidies. However, bread is being made from imported wheat, while its cultivation is not adapted to climate (10). The local production of wheat in Sudan is insufficient for local consumption, and the Sudanese mills spend a lot of money importing wheat flour for bread and other baked products (11). This situation emphasizing the need to find a replacement for wheat in bread making using local cereal, legumes, and root crops (12). Several developing countries have encouraged the setting up initiation of programs to evaluate the feasibility of alternative locally available flours as a substitute for wheat flour (13). Many efforts have been carried out to promote the use of composite flours in which locally grown crops replace a portion of wheat use in bread, thereby decreasing the demand for imported wheat (14). There are several studies using maize in bread making but most of them used other additives to improve the quality of processed bread. Therefore, the output of the research will be encouraging when the wheat is partially substituted with low quantities of non-wheat flours or starches. However, the bread produced from non-wheat flours will be acceptable compared to that made of wheat. In Sudan, the consumption of maize is constantly immature, fried, or boiled as a snack. Sometimes the maize flour is used for cooking traditional foods in some Sudanese tribes (15). Maize flour contains a good nutritional value, such as energy, carbohydrates and protein. In addition, it has functional properties in cooking and additional physical properties (16). Nowadays, it is possible to produce high-quality bread from 100% maize without any improvers, although there are scientific reservations regarding this issue. Therefore, this research comes within the framework of scientific verification of this circulation. The present study aims to evaluate the physicochemical, rheological, and sensory characteristics of bread processed from a blend of maize and wheat flour.

Materials and methods

Materials and chemicals

Maize was obtained from the crop market in Wad Medani. Then the samples were transported to the laboratories of the Food Engineering and Technology Department. The Maize was separated from any undesirable substances and then milled into flour. Chemicals, solvents, yeast; instant dry yeast, tap water, sugar, salt, and any other chemicals, materials, and reagents were of the highest grade commercially available. Maize and wheat grains were milled using a commercial mill after being cleaned very well.

Methods

Functional properties

Water absorption capacity

The water absorption capacity (WAC) was estimated by the method of Lin *et al*., (17) with the modification described by Quinn and Beuchat, (18). 0.5 gm of peanut flour added to 5 gm distilled water was stirred in a centrifuge tube using a glass rod for 2 minutes at room temperature (26°C). After 20 minutes of equilibration, the suspension was centrifuged for 20 minutes at 440 rpm at room temperature (26°C). The freed water was decanted into a 10 ml graduated cylinder and the volume was recorded.

Fat absorption capacity (FAC)

FAC of the samples was measured by a modified method by Lin *et al.* (17). 2 grams of the sample was treated with 20 ml of refined peanut oil in a 15 ml centrifuge tube. The suspension was stirred in a centrifuge tube using a glass rod for 2 minutes at room temperature (26°C). The suspension was centrifuged for 20 minutes at 440 rpm at room temperature (26°C). The freed fat was decanted into a 10 ml graduated cylinder, and the volume was recorded.

Bulk density (BD)

BD was determined by the method of Wang and Kinsella, (19). About 10 grams of material were placed in a 10 mL graduated cylinder and gently packed by tapping the cylinder on the bench (10) times to a reasonable height (approximately 5-8). The volume of the sample was recorded.

Foam capacity (FC)

FC was determined according to the method of Lawhon, *et al.*, (20). Flour (2 g) was dispersed in 100 ml of distilled water, and the contents were transferred to a mixer blender and whipped for 5 min. at high speed for 5 min. The contents, along with the foam, were poured into a 250 ml measuring cylinder; the foam volume was recorded after 30 s. FC was expressed as the percentage increase in volume. After 30 min, the volume of foam was measured and expressed as follows:

$$FC = \frac{\text{Volume after whipping} - \text{Volume before whipping} \times 100}{\text{Volume before whipping}}$$

Dough rheological properties

Gluten content

Wet gluten content was determined by washing the flour sample with a salt solution to remove the starch and other soluble compounds from the sample.

The residue remaining after washing was the wet gluten. This determination was adapted according to the AACC method (21). A 10g sample was weighed and placed into the glutamic-washing chamber on top of the polyester screen. The sample was mixed and washed with 2% salt solution (NaCl) for 5 minutes. At the end of the wash cycle, the wet gluten was removed from the washing chamber, placed in the centrifuge holder, and centrifuged. The residue that remained on top of the screen and through the screen was weighed to get the total gluten. Wet gluten content results were expressed as a percentage on a 14% moisture basis. It was then dried in a heater to give the dry gluten. Calculation of wet, dry, and gluten index was as follows:

$$\text{Wet gluten percentage} = \frac{\text{Total gluten}(g)}{\text{Sample weight}(g)} \times 100$$

$$\text{Dry gluten percentage} = \frac{\text{Weight of dry gluten}(g)}{\text{Sample weight}(g)} \times 100$$

$$\text{Gluten index} = \frac{\text{Wet gluten remaining in the sieve}(g)}{\text{Total wet gluten}(g)} \times 100$$

Least gelation capacity

The least gelation property was determined using the method described by Coffman and Garcia, (22). Sample suspensions of 2 to 16% were prepared in distilled water. Each aliquot dispersion (10 ml) was transferred into a test tube and heated in a boiling water bath for 1 h, cooled rapidly in a cold-water bath, and allowed to cool further at 4°C for 2 h. The least gelation concentration was determined when the sample from the inverted test tube did not slip or fall.

Bread-making

Preparation of composite flour blends

Maize flour, which was used for bread making, was 100, 75, 50, and 25%. The composite flours were stored in an air-tight container and kept until required. All ingredients were weighed and placed in a mixture (cereal technology laboratory) for mixing. The mixture ran for 5 seconds to mix dry flour, salt, oil, and sugar. Then a solution of the yeast in water was added. The mixture was run at high speed for one minute and 32 seconds, mixing time; water was added to the mixture. The dough temperature will be 84° – 90°F after mixing. The dough was transferred and scaled into three portions, rounded into balls by hand, then placed in a lightly greased fermentation bowl and placed in the fermentation cabinet at 86° F and 85% relative humidity for 20 minutes (23). Furthermore, the dough was passed through the sheeter lengthwise using width and spacing, then molded by hand and placed in lightly greased pans, and returned to the fermentation cabinet for final proof for 50 minutes. When the height of the dough had risen to about 1 – 2 cm from the pans, the pans were baked into bread in a convection oven at 415°F for 18 minutes (24). The oven will be preheated to 415°F and conditioned with a 1-L beaker full of water placed on the same shelf throughout baking. Loaves were weighed, and the volume was recorded immediately after removal from the oven. Then the bread was left to cool for 25 minutes and sliced using an electric knife of 1 cm width. Some slices were kept at room temperature in sealed plastic bags for sensory evaluation and physical characteristics.

Sensory evaluation

Semi-trained panelists were given a hedonic scale questionnaire to evaluate the bread samples after passing the triangle test. Maize bread was evaluated through crust color, crumb color, texture, flavor, and overall acceptability. The processed bread was evaluated based on crust color, texture, flavor, crumb color, and overall acceptability measures. They were scored on a scale of 9 points, which (1: extremely bad, 2: very bad, 3: bad, 4: fairly bad, 5: satisfactory, 6: fairly good, 7: good, 8: very good, 9: excellent). During the sensory evaluation, panelists were instructed to drink water or will be mouth after each evaluation. Sensory evaluation was done on the day on which the bread was prepared (25).

Proximate analysis of bread

Moisture content

Moisture determination was conducted using the AOAC, (21). Disposable aluminum weighing dishes (<50 mm diameter and <40 mm deep), which had been numbered, dried in the oven for 30 minutes, cooled in a desiccator, and weighed again, were used. A two-g sample was weighed out and repeated in triplicate. Using tongs, aluminum-weighing dishes containing the samples were placed in an air-drying oven at 130° C for about one hour. The samples were removed and placed in a desiccator to cool for 30 minutes and reweighed. The moisture content was calculated according to the following equation:

$$\text{Moisture Content} = \frac{W_1 - W_2}{\text{Moist samples weight}} \times 100$$

Where:
W_1 = Weight of dish and dry sample
W_2 = Weight of dish

Protein content

Protein content was determined according to Kjeladahel method described by (AOAC, 26). Two grams of each sample were placed in a digestion flask (500 ml), KSO_4 was added to it. Then 25 ml of concentrated sulfuric acid was added, and the content was heated at 35°C in a fume cupboard until a clear solution was obtained (2-3 hours) and left to cool before the antidumping granule was added. The digested samples were poured in a volumetric flask (100 ml) and diluted to 100 ml with distilled water. Five ml were distilled using 10 ml of 40% NaOH; 25 ml of boric acid with drops of methyl red were placed in a conical flask. Distillation of the reaction mixture liberated ammonia and reacted with boric acid, changing the color from red to light greenish blue. Excess alkali was then titrated using 0.1 N hydrochloric acid until the color changed to light purple. The titration reading was reported. The protein content was determined by multiplying the percentage nitrogen by the empirical factor 6.36; as follows:

$$\text{N \%} = \text{Volume of HCl} \times \text{N} \times 14 \times \frac{\text{Dilution factors}}{100 \times \text{Weight of sample}} \times 100$$

$$\text{Protein \%} = \text{N \%} \times 6.63$$

Where:
14 = Molecular weight of Nitrogen
N = Normality of acid, HCl

Ash content

The ash content was determined according to the AOAC method (21) using a muffle furnace. Four grams of the sample were weighed and repeated in triplicate into porcelain crucibles, which had been ignited, cooled in a desiccator, and weighed and placed in a cool electric muffle furnace. The temperature was 540°C overnight for complete ashing. The ash crucibles were transferred directly into a desiccator, then cooled for 30 minutes, and weighed immediately. The ash was determined by calculation and expressed as a percentage using the equation:

$$\text{Total ash}(\%) = \frac{\text{Ash weight}}{\text{Sample weight}} \times 100$$

Fat content

The fat content was determined according to the AOAC method (21) with some modifications. It was extracted with petroleum ether on a Goldfish extractor. Goldfish beakers were washed, dried, and labeled by placing them in an air oven at 130°C for one hour; then cooled in a desiccator for 30 minutes and weighed; repeated to constant weight. Samples of 2 g in triplicate were wrapped in filter paper and placed in a cellulose thimble condenser. 40ml of the solvent, petroleum ether, was added to the weighed Goldfish beakers. The extraction was carried out for 4 hours until all the soluble components of the sample were removed. Burners were allowed to cool for 30 minutes, then the beakers were moved to a tray, covered with an evaporation-type watch glass, and set in a hood to allow all ether to evaporate overnight. The air oven removed the traces of solvent at 130° C for 15 minutes; cooled in a desiccator for 30minutes and re-weighted. The fat content was calculated according to the following equation:

$$\text{Crude fat \%} = \frac{\text{Weight of oil extracted}}{\text{Weight of sample}} \times 100$$

Fiber content

The crude fiber was determined according to the official method of the AOAC (27). The crude fiber was determined gravimetrically after the sample was chemically digested in chemical solutions. The weight of the residue after ignition is then corrected for ash content and is considered a crude fiber. About 2 g ± 1 mg of a defatted sample was placed into a conical flask containing 200 m1 of H_2SO_4 (0.26 N). The flask was then fitted to a condenser and allowed to boil for 30 minutes. At the end of the digestion period, the flask was removed and the digest was filtered (under vacuum) through a porcelain filter crucible (No.3). After that, the precipitate was repeatedly rinsed with distilled boiled water followed by boiling in 200 ml NaOH (0.23 N) solution for 30 minutes under a reflux condenser and the precipitate was filtered, rinsed with hot distilled water, 20m1 ethyl alcohol (96%) and 20 ml diethyl ether. Finally, the crucible was dried at 105 ˚C (overnight) to a constant weight, cooled, weighed, and ashed in a Muffle furnace (No.20. 301870, Carbolite, England) at 550-600 ˚C until a constant weight was obtained.

Calculation

$$\text{Crude fiber}(\%) = \frac{W_1 - W_2}{\text{Sample weight}(\text{gm})} \times 100$$

Where:
W_1 = Weight of the sample before ignition (gm)
W_2 = Weight of the sample after ignition (gm)

Total carbohydrates

The number of carbohydrates was calculated by difference. The values refer to “total carbohydrate by difference,” that is, the sum of the figures for moisture, protein, fat, fiber, and ash is subtracted from 100.

Determination of physical properties

Loaf weight, volume, and specific volume

The weights of bread samples were determined after sufficient cooling using a digital balance (0.01 g accuracy), and the loaf volumes were determined using the rapeseed displacement method (28). The specific volume of each loaf was then calculated as:

$$\text{Specific volume}\left(\frac{\text{cm}^3}{\text{g}}\right) = \frac{\text{Loaf volume}}{\text{Loaf weight}}$$

Statistical analysis

Statistical analyses were conducted using Statistical Package for the Social Sciences (SPSS) software, version 16.0 for Windows (SPSS Inc., Chicago, IL.). One-way analysis of variance was used to report significant differences between means, and Tukey's test was used to carry out multiple comparisons between means. The significance level was defined as $p < 0.05$. Origin software version 8 (Microcal Software Inc., MA, USA) and Microsoft Office Excel® 2016 (Microsoft Corporation, Redmond, WA, USA) were used for plotting the scientific graphs.

Results

About the functional properties of maize and maize-wheat flour, in this study, water absorption and oil capacity, bulk density, and foaming capacity were determined as illustrated in Table 1 and Figure 1.

The water absorption capacity moisture for maize-wheat flour which has been added as 25%, 50 %, 75 %, and 100% maize flour, are shown in Tables 1 and were found to be 2.3 mL/g, 2.4 mL/g, 2.8 mL/g, and 3.0 mL/g, respectively, in comparison of the control (wheat flour) which was found to be the lowest (2.2 mL/g).

The oil-absorption capacity (OAC) is of great importance since it affects the emulsifying capacity, a highly desirable characteristic in products such as bakery products. The OAC for maize-wheat flour, which has been added as 25%, 50%, 75%, and 100% maize flour are shown in Table 1 and was found to be 1.2 mL/g, 1.5 mL/g, 1.7 mL/g, and 2.3 mL/g, respectively, compared with the value (2.0 mL/g) of wheat flour as a control. There were no significant differences between 50 and 75% maize flour, while there were differences found between the other ratio including the control. The increase in OAC of blends after incorporating

Table 1. Functional properties of the processed bread from maize-wheat flour

Maize flour blends	WAC (mL/g)	OAC (mL/g)	BD (mL/g)	FC (%)
25%	2.3±0.32^{b}	1.2±0.12^{d}	3.3±0.34^{c}	15.00±0.94^{b}
50%	2.4±0.14^{b}	1.5±0.44^{c}	4.0±0.34^{b}	12.30±0.31^{c}
75%	2.8±0.64^{a}	1.7±0.14^{c}	4.4±0.34^{a}	10.00±0.54^{d}
100%	3.0±0.31^{a}	2.3±0.64^{a}	4.5±0.34^{a}	7.50±0.32^{e}
Control	2.2±0.32^{b}	2.0±0.33^{b}	3.2±0.34^{c}	20.09±0.11^{a}

WAC: water absorption capacity; *OAC*: oil absorption capacity; *BD*: bulk density; *FC*: foaming capacity. All values were indicated as mean ± standard deviation. Values with different letters (a–b) in the same column are significantly different ($p < 0.05$) from each other. Control: wheat flour (100%) bread.

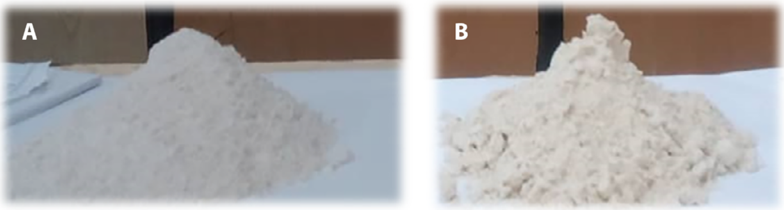

Figure 1. Maize and wheat flour, wheat A: Wheat flour; B: Maize flour.

maize flour may be due to an increase in the starch leaching, solubility, and loss of starch crystalline structure. OAC is defined as the difference in the flour weight before and after its oil absorption.

Bulk density (BD) is a property of powders defined as the mass of the many particles of the material divided by the total volume occupied. The total volume includes particle volume, antiparticle void volume, and internal pore volume. The BD for maize-wheat flour, which has been added in different percentages, is also shown in Table 1. The bulk density was increased with the incorporation level of maize flour with wheat flour (3.3 g/mL, 4.0 g/mL, 4.4 g/mL, and 4.5 g/mL, for 25%, 50%, 75%, and 100% maize-wheat flour, respectively), compared with wheat flour, which was found to be (3.2 g/mL).

Foaming capacity of maize-wheat flour is an important characteristic of most proteins. As shown in Table 1, the foaming capacity of maize-wheat flour, which has been added as 25, 50, 75, and 100% maize flour, was determined and found to be 15, 12.30, 10.0, and 7.5%, respectively, in comparison with wheat flour (20 %).

Rheological properties of maize-wheat flour paste in this study, some rheological characteristics (wet gluten, dry gluten, gluten index, and least gelation capacity) of maize-wheat flour in comparison to the control were determined, as can be seen in Table 2, and Figure 1.

Gluten can be defined as a composite of storage proteins termed prolamins and glutelins and stored together with starch in the endosperm (which nourishes the embryonic plant during germination) of various grass-related grains (29). The results of wet gluten percentage of maize-wheat were 2.96, 1.73, 0.95, and 0.74% for blends 25, 50, 75, and 100% maize-flour, respectively, compared with (3.0) for the control (wheat flour). There were significant differences ($p < 0.05$) among all the levels of maize blends, including the control (wheat flour).

As can be seen in Table 2, the dry gluten percentage of maize-wheat flour at 25, 50, 75, and 100% were found to be 1.0, 0.98, 0.30, and 0.20%, respectively, while the control (wheat flour) was found to be the highest (2.0%). According to these results, dry gluten was found to be decreased with an increase in the

Table 2. Gluten quantity and quality of composite flour of maize - wheat flour

Quality Characteristics	Control	Maize-wheat blends			
		25%	50%	75%	100%
Wet gluten (%)	3.0±0.21[a]	2.96±0.04[b]	1.73±0.22[c]	0.95±0.03[d]	0.74±0.22[e]
Dry gluten (%)	2.0±0.22[a]	1.0±0.09[b]	0.98±0.82[b]	0.30±0.21[c]	0.20±0.11[c]
Gluten index (%)	66.0±0.14[a]	62.0±0.09[b]	61.0±0.12[b]	60.0±0.17[c]	58.5±0.18[c]

All values are indicated as mean ± standard deviation. Values with different letters in the same row are significantly different ($p < 0.05$) from each other. Control: wheat flour (100%) bread.

incorporation of maize flour with wheat flour. Gluten is very susceptible to heat when wet, and relatively low temperatures destroy the cohesive, visco-elastic properties, which make it unique among food proteins.

The gluten index is the percentage of gluten remaining on the sieve. Thus, a high gluten index indicates strong gluten. The total wet gluten content is expressed as a percentage of the flour. As shown in Table 2, the gluten index of maize-wheat flour at 25, 50, 75, and 100% were found to be 62, 61, 60, and 58.5%, respectively, compared with the dry gluten of the control, which was found to be higher ($p < 0.05$).

The least gelation concentration (LGC), which is defined as the lowest protein concentration at which gel remained in the inverted tube, was used as an index of gelation capacity. The data for LGC of different percentages of maize flours are given in Figure 2. LGC results of maize-wheat flour 25, 50, 75, and 100% was 12.5, 7.8, 4.75, and 1.9%, respectively, compared with the control (16.0%), which was found to be the highest ($p < 0.05$). The lower the LGC, the better the gelating ability of the protein ingredient (30), and the swelling ability of the flour was enhanced.

Table 3 shows the proximate composition of maize-wheat bread. Although the nutritional value of bread can vary among different products, it is typically high in and low in fat and protein. While neither white nor white breads are especially high in fiber, whole breads usually contain more fiber than white breads. The bread commonly consumed is low content and usually contains unsaturated fat. It offers small amounts of some vitamins and vitamin B a few necessary. Proximate compositions (moisture, crude protein, ash, crude fiber, and total carbohydrates) of

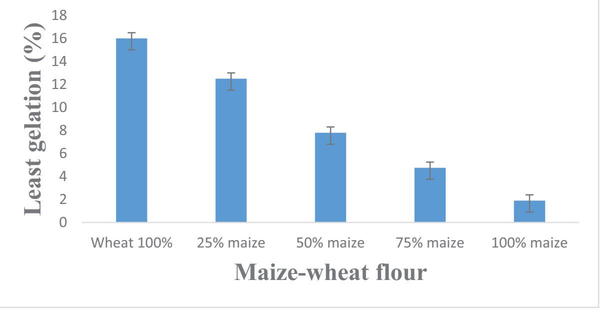

Figure 2. Least gelation capacity (percentage) of maize-wheat flours.

maize-wheat bread compared with wheat flour bread was determined (Table 3).

Moisture content of the maize-wheat bread with different percentages was 9.5, 9.0, 8.5, and 7.0%, respectively, which were found to be lower (10.0%) than the value of wheat flour bread (Table 3). This trend may be due to the presence of high levels of gluten in wheat flour bread and the high content of starch in maize and maize-wheat bread. The moisture content of maize-wheat flour bread decreased with an increase in the proportion of maize. The moisture content of maize-wheat flour was affected by blending, but there was no highly significant difference ($p < 0.05$).

As shown in Table 3, the protein content of maize-wheat bread blends (25, 50, 75, and 100%) was 9.70, 7.92, 5.67, and 3.25%, respectively. In comparison of these values with the control (wheat flour bread), these values were found to be lower ($p < 0.05$). Different types of wheat flour contain different amounts of protein. Unbleached all-purpose flour has the lowest amount of protein, usually around 10.5%. Bread flour

Table 3. Chemical composition of maize-wheat bread compared with the control

Type of flour	Moisture	Ash	Crude fat	Crude protein	Crude fiber	CHO
Control	10±0.10[a]	1.60±0.15[a]	2.06±0.12[e]	11.20±0.10[a]	2.19±0.10[e]	72.95±0.23[e]
Maize 25%	9.5±0.56[b]	1.30±0.22[d]	2.15±0.50[d]	9.70±0.20[b]	2.78±0.10[d]	74.57±0.51[d]
Maize 50 %	9.0±0.09[b]	1.41±0.35[c]	2.28±0.13[c]	7.92±0.15[c]	2.91±0.10[c]	76.75±0.58[c]
Maize 75%	8.5±0.51[c]	1.52.0±16[b]	2.39±0.03[b]	5.67±0.12[d]	3.09±0.10[b]	78.83±0.14[b]
Maize 100%	7.0±0.09[d]	1.69±0.17[a]	2.66±0.03[a]	3.25±0.11[e]	3.78±0.10[a]	81.62±0.19[a]

All values are indicated as mean ± standard deviation. Values with different letters in the same column are significantly different ($p < 0.05$) from each other. Control: wheat flour (100%) bread.

contains about 12 to 12.7%. High-gluten and whole-wheat flours have about 14% protein.

Ash content of maize-wheat bread was 1.30, 1.41, 1.52, and 1.69% for the percentages of maize addition 25, 50, 75, and 100%, respectively, while there was no significant difference ($p < 0.05$) between the control and maize bread. The same trend was reported by a previous study conducted by *et al.* (31), who investigated the effect of the incorporation of wheat with different grains. Ash is the mineral or inorganic material in flour.

As can be seen in Table 3, the crude fat content of the control bread (2.06%) was found to be lower ($p < 0.05$) when compared with maize-wheat bread (2.15, 2.28, 2.39, and 2.66% for maize-wheat 25, 50, 75, and 100%, respectively).

Crude fiber content of maize-wheat bread was found to be 2.78, 2.91, 3.09, and 3.78% for maize-wheat 25, 50, 75, and 100%, respectively, when compared these values with the control bread (2.19%) found to be higher ($p < 0.05$). High fiber bread is a whole wheat or whole grain bread that is enriched with extra fiber and contains at least four grams of fiber in a single serving. Extra fiber sources include wheat or oat bran, soy, or seeds.

The total carbohydrates contents found to be 74.57%, 76.75%, 78.83%, and 81.62% for the percentages of maize addition 25, 50, 75, and 100%, respectively, compared with the control bread (72.95%). Bread's high carbohydrate content can increase blood sugar and hunger while possibly promoting a higher body weight and an increased risk of diabetes and metabolic syndrome (32).

Sensory scores of maize-wheat bread samples made with substitution with maize flours are presented in Table 4 and Figure 3. The effect of wheat and maize blends on sensory properties was statistically significant ($p<0.005$) for all types of breads evaluated in this study.

Physical characteristics of composite maize-wheat bread for loaf weight, loaf volume, and specific volume are shown in Table 5.

Loaf weight decreased with an increase in the percentage of maize (138, 125, 112, and 107 g for maize-wheat bread 25, 50, 75, and 100%, respectively), compared with the control bread (145 g). There were significant differences among all samples ($p<0.05$).

Discussion and conclusion

Functional properties are the essential physicochemical properties of foods that reflect the complex interactions between the structures, molecular conformation, compositions, and physicochemical properties of food components with the nature of the environment and conditions in which these are measured and associated (33).

The increase in values of maize may be due to the high content of starch, which can absorb more moisture. Water binding with proteins is very important in the food system because of its effects on the flavor and texture of foods (34). Generally, the protein subunit structure dissociates on heating, and any possible factors that may affect these groups may cause changes in the water and oil absorption capacities. The water absorption

Table 4. Sensory evaluation of maize-wheat bread compared with the control

	Maize-wheat bread				
Sensory attributes	**25%**	**50%**	**75%**	**100%**	**Control**
Crust color	8.60[b]	7.80[c]	5.50[d]	3.60[e]	9.60[a]
Crumb color	7.60[b]	6.50[c]	5.20[d]	4.0[e]	9.0[a]
Texture	6.20[b]	5.70[c]	4.20[d]	3.20[e]	8.20[a]
Flavor	8.10[b]	7.00[c]	6.70[d]	4.10[e]	9.10[a]
Overall acceptability	7.50[b]	6.40[c]	5.90[d]	4.20[e]	8.20[a]

Mean values having different superscript letter(s) in each row differ significantly ($p<0.05$). Control: wheat flour (100 %) bread.

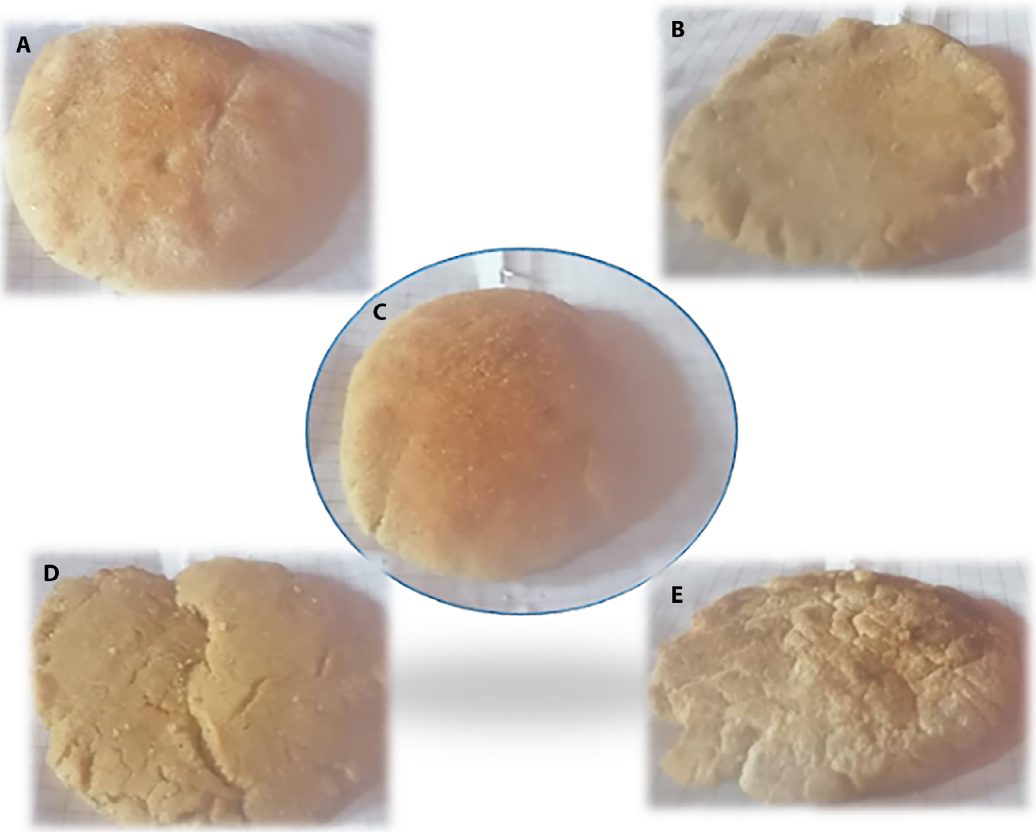

Figure 3. Maize-wheat bread compared with the control (wheat bread) (A): 25% maize; (B): 50% maize; (C): Control: wheat flour (100%) bread.; (D): 75% maize; (E): 100% maize.

A gluten index test was recently introduced as a quicker method to measure wheat processing quality in comparison with the classical instrumental methods, such as a mixograph and a farinograph.

Vautsinas and Nakai (43) reported that protein gelation was significantly affected by exposed hydrophobicity and the square of sulfhydryls of proteins. As the percentage of incorporation of maize flour with

Table 5. Physical characteristics of composite maize-wheat bread compared with the control

Sensory attributes	Maize bread blends				Control
	25%	50%	75%	100%	
Loaf weight (g)	138±0.32[b]	125±0.44[c]	112±0.13[d]	107±0.39[e]	145±0.33[a]
Loaf volume (cm^3)	466±0.12[b]	459±0.43[c]	445±0.42[d]	439±0.41[e]	479±0.42[a]
Specific volume(cm^3/g)	3.38 ±0.44[d]	3.67±0.87[c]	3.97±0.55[b]	4.10±0.80[a]	3.30±0.7[d]

All values are indicated as mean ± standard deviation. Values with different letters in the same row are significantly different (p< 0.05) from each other. Control: Wheat flour (100%) bread.

capacity is an important functional property of flours due to swelling, and it affects the characteristics of body thickness and viscosity (35). No significant difference between 25-50% and 75-100% was observed in maize addition (p<0.05) related to water absorption capacity. The water absorption capacity is an important functional property of flours due to swelling, and it affects the characteristics of body thickness and viscosity (36). The flour with high water absorption may have more hydrophilic constituents, such as polysaccharides. Protein has both a hydrophilic and hydrophobic nature and therefore can interact with water in foods.

It is of great importance, since fat acts as a flavor retainer and increases the soft texture of the mouth feel of foods, especially bread and other baked foods (37). It is suggested that the high oil-absorption capacity of maize flour could be utilized in the food industry, for ground meal formulation, but for bread making is not suitable to use as a blend according to the results of this study. However, the flours in the present study are potentially useful in structural interaction in food, especially in flavor retention, improvement of palatability, and extension of shelf life, particularly in the bakery or meat products where fat absorption is desired (38). The major chemical component affecting OAC is protein, which is composed of both hydrophilic and hydrophobic parts. Non-polar amino acid side chains can form hydrophobic interactions with hydrocarbon chains of lipids (39).

The present study revealed that BD depends on the particle size and initial moisture content of flours. BD of composite flour increased with an increase in the incorporation of maize flour with wheat flour. Decreasing the proportion of wheat flour increases the BD of composite flours. The high bulk density of flour suggests its suitability for use in food preparations, but bread-making is considered not considered suitable. In contrast, low bulk density would be an advantage in the formulation of complementary foods (40).

The foam capacity of a protein refers to the amount of interfacial area that can be created by the protein (41). Foam is a colloidal suspension of many gas bubbles trapped in a liquid or solid. Thin liquid films surround small air bubbles. According to these results, foaming capacity was found to be decreased (p< 0.05) with an increase in the incorporation of maize flour with wheat flour. There was an inverse relationship between foam capacity and foam stability. Flours with high foaming ability could form large air bubbles surrounded by a thinner, less flexible protein film. These air bubbles might be easier to collapse and consequently lower the foam stability (39).

Gluten is appreciated for its properties. It gives elasticity, helping it and keep its shape, and often gives the final product a texture (42). Gluten has such a wide range of functions in traditional baking that it is not possible to replace wheat flour with one single ingredient bread system. Several functional ingredients are required to develop the bread with desirable characteristics like good volume and crumb structure.

Attempts to dry gluten while retaining these properties were unsuccessful until the application of the ring drier to gluten in the first half of the twentieth century (29). Gluten is a structural naturally found in certain grains. Although particularly, "gluten" pertains only to wheat proteins, in medical literature, it refers to the combination of and proteins naturally occurring in all grains that have been proven capable of triggering. These include any species of, and some cultivars, as well as any cross-hybrids of these grains (42).

wheat flour increased, gelling properties decreased ($p< 0.05$). The low gelation concentration of maize-wheat may be an asset for the formation of curd or as an additive to other gel-forming materials in food products. The variation in the gelling properties may be ascribed to ratios of the different constituents, such as protein, carbohydrates, and lipids in different composite flours, suggesting that interaction between such components may also have a significant role in functional properties (38). Least gelation concentration values were compared favorably with those reported for African yam bean (16 - 20%) by Abbey and Ayuk (44). However, lower values were recorded for several *Phaseolus* species and Lablab bean by Chau and Cheung, (45), and Deshpande *et al.*, (46). Sathe *et al.*, (47) also reported an LGC of 12 % for black gram flour. The LGC for other flours such as lupin, cowpea, plantain, safflower, and maize flour (48) were 14, 6, 6, 8, and 6% (w/v). The composite flours (W85, W70, and W55) would be useful in food systems such as puddings, sauce and other foods, which require thickening and gelling (49).

Bread is high in calories and carbohydrates but low in protein, fat, fiber, and many vitamins and minerals. However, the specific nutrient profile depends on the type of bread. Bread contains gluten, which can cause adverse side effects for people with celiac disease or gluten sensitivity (50). Proportionally, whole wheat bread does contain abundant amounts of one out of the nine essential amino acids. However, whole wheat bread is a little short on histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine. To have adequate amounts of all nine essential amino acids with whole wheat bread alone, 24 slices of whole wheat bread (623 grams) consumption is need for an average person (51). That is about 67% more whole wheat bread to compensate for the lack of histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, and valine, compared to the protein requirement alone (50).

Both moisture content and water activity, the ratio of the water vapor pressure of a substance, such as food, to the water vapor pressure of pure water under the same conditions, are how much important in formulating products for safety and stability (52). Moisture content is amount of water in a product. It influences the physical properties of a substance, including weight, density, viscosity, conductivity, and others. It is generally determined by weight loss upon drying. The same trend of this study is similar to that observed by Begum et al., (3), who found that the moisture content of maize-wheat flour bread decreased with an increase in the proportion of maize.

The ash content of any flour is affected primarily by the ash content of the wheat from which it was milled, and its milling extraction rate: the amount of flour obtained from wheat after milling, when the bran and germ are removed, leaving the endosperm (53). The ash content of flour cannot, however, be taken as an unequivocal index of flour extraction for two previously mentioned reasons: (a) the mineral content of wheat varieties cultivated under different growth conditions can vary markedly, and (b) not all wheat varieties have the same mineral content gradient from the peripheral tissues of the wheat kernel to the endosperm. Since the bran portions of wheat contribute to the color of flour, the objective measurement of flour color may be a more reliable indication of its quality (54).

Bread is a low-fat food. An average medium slice of white bread contains 0.6 g of fat, brown bread contains 0.7 g, and whole meal bread contains 0.9 g. Just be careful with what you put on it and stick to healthy options for spreads and toppings (55).

There is no recognized definition of what constitutes a high diet, and the amount of fiber consumed in the typical human diet varies significantly by region, with 20 daily grams at the low end and 80 grams at the high end (56). Most Americans consume about 15 grams daily. Fiber from whole-grain bread may be better for reducing heart disease risk than fruits and veggies; a study suggests whole-meal bread keeps you fuller longer than white bread (57). Fiber from foods like vegetables and grains is important for digestion, metabolism, and longevity. Whole-grain fiber may have unique benefits over other foods for heart health, new research suggests. Fiber sources like dark bread, bran, and cereals may help lower inflammation and heart disease risk (58).

Bread has been a staple food for humans for thousands of years and is a key component of many people's diets (59). Modern bread usually contains refined wheat, which is relatively high in carbohydrates.

Reducing the number of carbs in the diet by eliminating bread may help some people lose weight or reduce their risk of specific disorders (60).

All sensory scores, crust color, crumb color, texture, flavor, and overall acceptability were significantly different among blended samples, except at the level 25% maize-wheat bread. The lowest scores for appearance were given to the 100, 75, and 50% maize-wheat, respectively, which were much paler than the other breads (Figure 2). The control bread (100% wheat) achieved the highest score. According to the results in Table 4, bread made from 100% wheat flour (control) showed excellent attributes in comparison with other types of bread. The results showed that the level of preference declined with the decrease in the level of wheat flour substitution in the bread. This can probably be explained by the fact that the taste of wheat starch was much more similar to conventional bread. With regard to the overall acceptability, the bread with the lowest score was again the maize-starch bread, and the highest score was for the bread with wheat starch and rice flour. Our results confirmed those reported by Lopez et al., (61), which indicated that rice-flour bread is generally better rated with regard to appearance, taste, and overall acceptability than maize-starch bread. Matos and Rosell, (62) studied the characteristics of gluten-free breads from different commercial doughs. Most of them were made from maize starch, except for one, containing a mixture of maize starch and rice flour. In this study, the mixture formulation also exhibited the highest score for the parameters measured.

Loaf weight reduction during baking has an impact on bread quality attributes, as consumers are often attracted to bread with high weight and volume, believing that it has more substance for the same price (63). Loaf volume decreased with an increase in the level of maize addition, which was found to be 466, 459, 445, and 439 cm^3, for 25, 50, 75, and 100% maize-wheat bread, respectively, compared with the control (479 cm^3), which was found to be significantly higher ($p<0.05$). Bread volume is probably the most important external characteristic of bread. It is a key aspect of consumers' appeal as well as the quality control program of bread baking (64). This is often an indication of a good aerated crumb and superior texture, proper formulation and quality of ingredients, dough handling, gas retention, as well as processing conditions (65). About specific volume, the trend was found to be increased with an increase in percentage of maize addition (3.38, 3.67, 3.97, and 4.10 for maize-wheat bread 25, 50, 75, and 100%, respectively) compared with the control (3.30), which was found not significantly different compared with 25% maize-wheat bread sample ($p<0.05$). These data show that bread-specific volume cannot be considered individually as a quality indicator for gluten bread, as consumers also value other parameters, such as crust brightness and cell density (66). The addition of maize flour to this kind of product has the advantage of a better taste and less crust brightness (67). At the same time, it has the disadvantage of a lower specific volume and cell density, which can be improved by the addition of food additives such as guar to the mixtures, since in all cases it gave better results than maize for the manufacture of an optimal bread (68). Specific volume is one of the most commonly used parameters to evaluate bread quality, when it is maximized, the value obtained which indicates optimal dough formulation, gas retention, and crumb structure (69).

Conclusion

This research work, approve that the replacement of wheat flour by maize reduced the water, particularly when the replacement rate increased, due to the lower levels of gluten. The functional properties of maize-wheat flour, such as water absorption capacity, oil absorption capacity, and bulk density, were increased with an increase in the incorporation of wheat flour. However, the foaming capacity was found to be decreased with the increase in maize flour. Even though the only significant difference was observed with the maximum replacement of maize (25%). Bread's crumb and crust color showed a significant difference between bread made of 50, 75, and 100 % maize substitution and the control and maize-wheat flour at 25%. Thus, this study has demonstrated that the quality of composite bread has been adversely affected by the different substitution levels of maize flour. Maize flour may be used in composite flour bread preparation at the level of 25% with acceptable physical and sensory attributes.

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