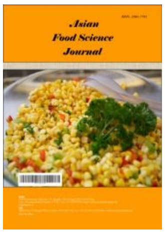

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Physical and Sensory Properties of Bread Made with Wheat and Fermented Finger Millet (*Eleusine coracana L.*) Flours

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Authors' contributions

This work was carried out in collaboration among all authors. Authors BEA and JAA designed the conceptual framework, mapped out the technical details, carried out the empirical analysis and made the write-up of the manuscript. Author VF contributed in improving the conceptual design framework and the technical analysis and gave maximum support to write the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The study was conducted to determine the effect of fermented finger millet flour supplementation in wheat on the physical and sensory properties of bread.
Methodology: Finger millet grains were cleaned, washed and fermented in deionized water for 72 h at room temperature (27±2ºC), with sampling at every 24 h interval. Fermented grains were washed, drained, dried (65ºC, 4 h), milled and sieved (<250 µm) to produce Fermented Finger Millet Flour (FFMF). Composite flour was formulated by supplementing wheat flour with Fermented Finger Millet Flour (FFMF) at 0, 5, 10, 15 and 20 % (w/w), and used to produce bread samples. Physical (Oven spring, loaf weight, loaf volume and specific volume) and sensory (crust colour, crumb colour, aroma, texture, taste, mouth feel and overall acceptability) properties of the bread samples were determined.
Results: Physical properties showed less oven spring, loaf volume and specific loaf volume and increased loaf weight with increased FFMF replacement. The sensory analysis showed significant

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differences (p<0.05) between 100% wheat bread and FFMF supplemented samples in all the determined sensory properties. It was concluded that fermentation period of 24-48 h, and substitution of 5-10% FFMF into wheat gave the bread samples with the best overall acceptability.

Keywords: Finger millet; finger millet flour; wheat flour; fermentation; bread; anti-nutritional factors; antioxidant activity; composite flour; physical properties; sensory evaluation.

1. INTRODUCTION

Bread is often described as a fermented confectionary product made majorly from wheat flour, yeast, salt and water by a series of operations such as mixing, moulding, proofing, shaping and baking [1]. As a staple food, bread is produced from flour dough mixed with water, and then subjected to baking. It is a popular food prepared by baking flour dough with water and often addition of other ingredients, such as butter, salt, sugar etc to enhance the taste. Bread is one of the oldest and prepared man-made foods and all through recorded history it has been a popular and commonly consumed food in many parts of the world, having been of great significant importance since the dawn of agriculture. In Nigeria, the eaten of bread is well known, but the less protein amount of wheat flour, which is the most essential ingredient used for bread production and other baked foods like biscuits, doughnuts, and cakes has been major concern [2]. In Nigeria, the eaten of bread is well known, but the less protein amount of wheat flour, which is the most essential ingredient used for bread production and other baked foods like biscuits, doughnuts, and cakes has been major concern [2]. In developing country where animal protein supply is insufficient to meet the rapid population growth, considerable interests have been indicated in incorporating high-protein, lysine, vitamin and mineral materials (especially protein concentrates, oilseed and legume flours, isolates and some cereal grains such as finger millet) into wheat flour to enhance the essential amino acid balance and other micronutrients of flour-based baked products and this increases the protein, vitamin and mineral contents [2].

Finger millet (*Eleusine coracana* (*L.*) GAERTN.) also known as *Ragi*, *Nagli* or *Nachani*, is one of the essential millets in many areas of Africa and India [3,4]. It originated in Ugandan and Ethiopian highlands (East Africa) and reached India in 2000 BCE [5]. The capacity to tolerate production at altitudes over 2000m above sea level, its important micronutrients (particularly its high methionine and iron content), its high drought resistance and the long shelf-life of the grains are the interesting crop attributes of finger millet [6]. The major cultivation areas are Southern and Eastern African countries (Uganda, Kenya, Zaire, Zimbabwe, Zambia, Sudan, Tanzania, Nigeria and Mozambique) and Southern Asia (mainly India and Nepal). Research shows that outcome of about 1,500 kg/ha from 2.8 million ton of yearly production of finger millet, widely grown as a cereal crop in southern region and hilly parts of India and is extensively consumed as dumpling by large part of the people [7]. Besides, it can withstand soil salinity to some certain level and can tolerate averagely alkaline soils (pH 8.2) and also averagely acidic soils (pH 5) [8]. The seeds are rarely destroyed by insects and moulds and can last extremely well once harvested. When unthreshed, finger millet can be kept for up to 10 years. Under good storage conditions, some sources reported a storage duration of up to 50 years for finger millet. The long shelf-life capacity of finger millet makes it an essential crop in risk-avoidance strategies as a famine crop for poor or low farming communities.

Finger millet is a rich source of carbohydrate, calcium, phosphorus, iron, thiamine, riboflavin, folic acid, niacin, with a well-balanced amino-acid profile such as methionine, cysteine and lysine, these essential amino acids will be of great benefit especially to those that depend totally on plant foods for their protein nourishment, but underutilized due to the small grain size and the presence of Anti-nutritional Factors (ANF) such as tannins, oxalate, phytates, protease inhibitors etc. The ANF prevent the effective or efficient utilization of its essential nutrients. Fermentation as a processing method has been reported to reduce ANF, and its application in finger millet processing is recently becoming pronounced, hence supplementation of wheat flour with Fermented Finger Millet Flour (FFMF) can serve as a practical and sustainable approach to increase its utilization and at large reduce the incidence of malnutrition among vulnerable groups in Nigeria. To further the utilization of FFMF, the current study was designed to evaluate the effect of FFMF (at different fermentation period) supplementation in wheat flour on the physical and sensory properties of bread.

2. MATERIALS AND METHODS

2.1 Collection of Grains

Finger millet grains (*Eleusine coracana*) were procured from a local market in Ogbomoso, Nigeria and transported to the laboratory in an airtight polyethylene bag and stored at room temperature (27±2^{o}C) until needed.

2.2 Fermentation

The method of Akinyele and Akinlosotu [9] was used for fermentation of finger millet grains with a slight modification. Five hundred grams (500 g) of the finger millet grains were cleaned, washed and fermented in 1½ L of deionized water for 72 h at room temperature (27±2^{o}C), and samples were taken at 24 h interval. The fermented grains were washed, drained, dried (65^{o}C, 4 h) in cabinet dryer and milled into flour (<250 µm), packaged and stored at room temperature, prior to processing and analysis. This process is shown in Fig. 1.

2.3 Preparation of the Flour Blends

Wheat flour was supplemented with fermented finger millet flour at 0, 5, 10, 15 and 20 % (w/w), for 0, 24, 48, and 72 h fermented samples respectively.

2.4 Preparation of Bread

Bread samples were produced using the recipes in Table 1. The ingredients were mixed for 5 min in a mixer. This was followed by a rest period of about 15 min in order to relieve residual stress that may occur during mixing. The dough was moulded into 0.2 mm thick cylindrical shape aluminium container. After making the dough, it was proofed for 45 min at 35^{o}C in the pre-oiled baking pans and then baked until it attained and maintained baking temperature (about 265^{o}C) for 45 min according to the method of Oladunmoye *et al.* [10].

Finger millet grains

↓

Cleaning

↓

Washing

↓

Fermentation (72 h)

↓

Washing

↓

Draining

↓

Cabinet drying (65^{o}C, 4 h)

↓

Milling into flour (<250 µm)

↓

Packaging (in ziplock bags)

↓

Storage (at room temperature)

Fig. 1. Fermentation and flour production of finger millet grains

Table 1. Recipe used for the bread dough preparation

Ingredient	Control	5%	10%	15%	20%
Wheat flour (g)	300	285	270	255	240
Finger millet flour (g)	-	15	30	45	60
Yeast (g)	10	10	10	10	10
Sugar (g)	20	20	20	20	20
Salt (g)	7.5	7.5	7.5	7.5	7.5
Water (ml)	100	112.5	125	137.5	140
Shortening (g)	17.5	17.5	17.5	17.5	17.5

Source: Oladunmoye et al. (2010)

2.5 Physical Properties of Bread

The following physical properties were evaluated on the bread samples produced:

2.5.1 Oven spring

Oven spring was estimated from the difference in height of dough before and after baking.

2.5.2 Loaf weight

This was measured 30 min after the loaves have been removed from the oven using a digital weighing balance and the readings recorded in grams.

2.5.3 Loaf volume

Loaf volume was determined using rapeseed displacement method [11]. Finger millet seeds were loaded into an empty box with calibrated mark until it reached the marked level and then unloaded. The bread samples were placed into the box and the measured finger millet loaded back again. The remaining finger millet seeds left outside the box were measured using measuring cylinder and recorded as loaf volume in cm^3.

2.5.4 Specific volume

This was calculated by dividing the loaf volume by its corresponding loaf weight (cm^3/g) as described by Araki et al*.* [12].

2.6 Sensory Evaluation

Bread samples produced from the control and treatment flours were subjected to sensory evaluation. The loaves of bread were presented in random order and panelists were asked to evaluate each loaf for crust colour, crumb colour, aroma, texture, taste, mouth feel, and overall acceptability. Semi-trained 25-member panel comprises a broad cross section of adult population (students and staff) of Ladoke Akintola University of Technology (LAUTECH) Ogbomoso carried out this evaluation, with panelists spread across a wide range of people who are conversant with the consumption of bread. A 9-point hedonic scale was used where 1=dislike extremely to 9=like extremely. A score of 5 or above was considered a limit of acceptability for all sensory attributes tested as described by Makinde and Akinoso [13].

2.7 Statistical Analysis

All the analyses reported in this study were carried out in triplicates and data obtained were reported as mean ± standard deviation. Data were subjected to one-way analysis of variance to determine the statistical significance of the results, and significant means were separated using Duncan's New Multiple Range (DNMR) Test at a significant level of $p<0.05$ using SPSS version 25.0.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Bread Samples

Results of the physical properties of composite bread samples containing different levels of Unfermented Finger Millet Flour, 24, 48 and 72 hours Fermented Finger Millet Flour (FMFF) supplemented at 0, 5, 10, 15 and 20% are given in Tables 2, 3, 4 and 5 respectively.

The oven spring, loaf weight, loaf volume and specific loaf volume of the control bread (100% wheat bread) were found to be 1.01 cm, 462.70 g, 1808 cm^3 and 3.91 cm^3/g respectively. The oven spring and loaf weight of the composite bread samples containing different levels of unfermented FMF substitution ranged from 0.61 to 0.71 cm, and 471.80 to 488.00 g respectively. The oven springs were significantly different from the control bread at ($p<0.05$). The loaf and specific volumes of the composite bread samples containing different levels of unfermented FMF substitution ranged from 1420.00 to 1766.00 cm^3, and 2.91 to 3.74 cm^3/g respectively which were significantly different from the control (100% wheat bread).

Table 2. Physical Characteristics of Bread Samples from Unfermented FM Flour

Sample	Oven Spring (cm)	Loaf Weight (g)	Loaf Volume (cm^3)	Specific Vol. (cm^3/g)
AXY	1.01 ± 0.03^{b}	462.70 ± 0.15^{a}	1808.00 ± 0.23^{d}	3.91 ± 0.04^{d}
ATU	0.71 ± 0.02^{a}	471.80 ± 0.16^{b}	1766.00 ± 0.24^{c}	3.74 ± 0.04^{c}
AMW	0.68 ± 0.01^{a}	475.30 ± 0.14^{b}	1697.00 ± 0.20^{b}	3.57 ± 0.05^{c}
AZQ	0.64 ± 0.02^{a}	484.20 ± 0.13^{c}	1462.00 ± 0.21^{a}	3.02 ± 0.05^{b}
ANS	0.61 ± 0.01^{a}	488.00 ± 0.11^{c}	1420.00 ± 0.22^{a}	2.91 ± 0.08^{a}

Values are means of triplicate readings
Means within the same column with different superscripts are significantly different ($p<0.05$)
AXY=0% Unfermented Finger Millet Flour (UFMF) Substitution, ATU=5% UFMF Substitution, AMW=10% UFMF Substitution, AZQ=15% UFMF Substitution, ANS=20% UFMF Substitution

Table 3. Physical Characteristics of Bread Samples from 24 h Fermented FM Flour

Sample	Oven Spring (cm)	Loaf Weight (g)	Loaf Volume (cm^3)	Specific Vol. (cm^3/g)
BXY	0.98 ± 0.09^{d}	466.00 ± 0.10^{a}	1849.00 ± 0.23^{e}	3.97 ± 0.05^{e}
BTU	0.81 ± 0.08^{c}	467.00 ± 0.11^{a}	1775.00 ± 0.24^{d}	3.80 ± 0.05^{d}
BMW	0.51 ± 0.06^{b}	469.00 ± 0.13^{b}	1581.00 ± 0.21^{c}	3.67 ± 0.01^{c}
BZQ	0.49 ± 0.05^{b}	500.00 ± 0.15^{b}	1486.00 ± 0.20^{b}	2.97 ± 0.04^{b}
BNS	0.41 ± 0.03^{a}	506.00 ± 0.19^{c}	1402.00 ± 0.26^{a}	2.77 ± 0.03^{a}

Values are means of triplicate readings
Means within the same column with different superscripts are significantly different ($p<0.05$)
BXY=0% Fermented Finger Millet Flour (FFMF) Substitution, BTU=5% FFMF Substitution, BMW=10% FFMF Substitution, BZQ=15% FFMF Substitution, BNS=20% FFMF Substitution

Table 4. Physical Characteristics of Bread Samples from 48 h Fermented FM Flour

Sample	Oven Spring (cm)	Loaf Weight (g)	Loaf Volume (cm^3)	Specific Vol. (cm^3/g)
CXY	1.51 ± 0.03^{c}	433.00 ± 0.11^{a}	1688.00 ± 0.22^{e}	3.90 ± 0.05^{d}
CTU	1.48 ± 0.02^{c}	438.00 ± 0.10^{a}	1401.00 ± 0.24^{d}	3.20 ± 0.06^{c}
CMW	1.01 ± 0.04^{b}	449.00 ± 0.13^{b}	1281.00 ± 0.24^{c}	2.85 ± 0.04^{b}
CZQ	0.51 ± 0.01^{a}	466.00 ± 0.14^{c}	1248.00 ± 0.21^{b}	2.68 ± 0.03^{b}
CNS	0.48 ± 0.02^{a}	473.00 ± 0.15^{d}	1101.00 ± 0.22^{a}	2.33 ± 0.02^{a}

Values are means of triplicate readings
Means within the same column with different superscripts are significantly different ($p<0.05$)
CXY=0% Fermented Finger Millet Flour (FFMF) Substitution, CTU=5% FFMF Substitution, CMW=10% FFMF Substitution, CZQ=15% FFMF Substitution, CNS=20% FFMF Substitution

Table 5. Physical Characteristics of Bread Samples from 72 h Fermented FM Flour

Sample	Oven Spring (cm)	Loaf Weight (g)	Loaf Volume (cm^3)	Specific Vol. (cm^3/g)
DXY	1.28 ± 0.03^{c}	451.00 ± 0.15^{a}	1931.00 ± 0.24^{e}	4.29 ± 0.15^{e}
DTU	0.51 ± 0.02^{b}	452.00 ± 0.15^{a}	1898.00 ± 0.25^{d}	4.20 ± 0.14^{d}
DMW	0.48 ± 0.02^{b}	459.00 ± 0.17^{b}	1521.00 ± 0.23^{c}	3.31 ± 0.11^{c}
DZQ	0.45 ± 0.02^{b}	466.00 ± 0.13^{c}	1411.00 ± 0.20^{b}	3.03 ± 0.10^{b}
DNS	0.31 ± 0.01^{a}	469.00 ± 0.16^{c}	1218.00 ± 0.21^{a}	2.60 ± 0.13^{a}

Values are means of triplicate readings
Means within the same column with different superscripts are significantly different ($p<0.05$)
DXY=0% Fermented Finger Millet Flour (FFMF) Substitution, DTU= 5% FFMF Substitution, DMW=10% FFMF Substitution, DZQ=15% FFMF Substitution, DNS=20% FFMF Substitution

The oven spring, loaf weight, loaf volume and specific loaf volume of the composite bread samples having different levels of 24 h FFMF substitution ranged from 0.41 to 0.81 cm, 467.00 to 506.00 g, 1402 to 1775 cm^3 and 2.77 to 3.80 cm^3/g respectively. While the oven spring, loaf weight, loaf volume and specific loaf volume of the control bread were found to be 1.51 cm, 433.00 g, 1688 cm^3 and 3.89 cm^3/g respectively, the oven spring, loaf weight, loaf volume and specific loaf volume of the composite bread samples containing 48 h FFMF ranged from 0.48 to 1.48 cm, 438.00 to 473.00 g, 1101.00 to 1401.00 cm^3, and 2.33 to 3.19 cm^3/g respectively. The oven spring, loaf weight, loaf volume and specific loaf volume of the control bread and those produced from composite of wheat and 72 h FFMF at different levels of supplementation had ranges of ranged from 0.31 to 1.28 cm, 451.00 to 469.00 g, 1218.00 to 1931.00 cm^3 and 2.59 to 4.28 cm^3/g respectively.

In this study, a significant reduction in the physical characteristics of the bread was observed except loaf weight which was observed to increase with increased supplementation of FM flour ($p<0.05$). That is, there was a significant increase in the loaf weight of the composite bread samples at ($p<0.05$). In contrast, increased supplementation with FM flour reduced the specific volume, oven spring and loaf volume of the composite bread samples significantly. The observed increase in loaf weight resulted from the low retention of carbon dioxide gas in the blended dough, hence providing dense bread texture [14]. The less specific volume, oven spring and loaf volume of the composite breads resulted from the dilution effects on gluten with addition of finger millet to the wheat flour [15].

The fraction of gluten causes the dough elasticity by making it to extend and trap the carbon dioxide produced by the yeast during fermentation. During baking under the influence of heat, when gluten coagulates it serves as the framework of the loaf, which becomes relatively rigid and does not collapse. Moreover, increase in fibre content of composite flour arising from FM addition may have pronounced effects on dough characteristics resulting in higher water absorption, tenacity and mixing tolerance, and smaller extensibility as compared to those obtained without fibre addition [15]. Similarly, the adverse effects of addition of fibre on dough structure and loaf volume have been indicated to be as a result of the dilution of gluten network, which inversely affects gas retention rather than gas production [15].

3.2 Sensory Evaluation of Bread Samples

Sensory properties of bread samples containing unfermented FMF, 24 h, 48 h and 72 h FFMF substitution at different levels as compared to the control are given in Tables 6, 7, 8 and 9 respectively.

Table 6. Sensory Scores of Bread Samples from Unfermented Finger Millet Flour

Sample	Crust Colour	Crumb Colour	Aroma	Texture	Taste	Mouth Feel	Overall Acceptability
AXY	7.40 ± 0.32^{c}	7.62 ± 0.23^{c}	7.04 ± 0.17^{b}	6.56 ± 0.45^{c}	6.56 ± 0.42^{a}	6.20 ± 0.91^{a}	6.52 ± 0.19^{a}
ATU	6.40 ± 0.14^{c}	6.40 ± 0.41^{c}	6.76 ± 0.42^{b}	6.44 ± 0.26^{ab}	6.12 ± 0.88^{a}	6.00 ± 0.50^{a}	6.48 ± 0.48^{a}
AMW	5.88 ± 0.81^{ab}	5.48 ± 0.71^{ab}	6.52 ± 0.96^{ab}	5.48 ± 0.58^{ab}	5.92 ± 0.49^{a}	5.88 ± 0.74^{a}	6.20 ± 0.38^{a}
AZQ	5.72 ± 0.26^{ab}	5.00 ± 0.13^{ab}	6.20 ± 0.76^{ab}	5.24 ± 0.17^{a}	5.60 ± 0.16^{a}	5.56 ± 0.14^{a}	5.88 ± 0.01^{a}
ANS	5.24 ± 0.19^{a}	4.42 ± 0.15^{a}	5.60 ± 0.85^{a}	4.92 ± 0.06^{a}	5.48 ± 0.16^{a}	5.28 ± 0.15^{a}	5.68 ± 0.23^{a}

Values are means of 25-member panel scores
Means within the same column with different superscripts are significantly different (p<0.05)
AXY=0% Unfermented Finger Millet Flour (UFMF) Substitution, ATU=5% UFMF Substitution, AMW=10% UFMF Substitution, AZQ=15% UFMF Substitution, ANS=20% UFMF Substitution

Table 7. Sensory Scores of Bread Samples from 24 h Fermented Finger Millet Flour

Sample	Crust Colour	Crumb Colour	Aroma	Texture	Taste	Mouth Feel	Overall Acceptability
BXY	7.48 ± 0.23^{d}	7.50 ± 0.32^{d}	6.40 ± 0.73^{b}	6.96 ± 0.28^{b}	6.72 ± 0.51^{b}	6.36 ± 0.22^{a}	7.24 ± 0.30^{c}
BTU	6.60 ± 0.44^{cd}	6.80 ± 0.34^{d}	5.96 ± 0.72^{b}	6.64 ± 0.41^{b}	5.84 ± 0.97^{ab}	6.16 ± 0.95^{a}	6.56 ± 0.36^{bc}
BMW	6.12 ± 0.69^{bc}	6.34 ± 0.58^{c}	5.56 ± 0.81^{ab}	6.16 ± 0.89^{ab}	5.60 ± 0.18^{ab}	5.88 ± 0.74^{a}	6.08 ± 0.68^{b}
BZQ	5.56 ± 0.14^{ab}	5.44 ± 0.12^{ab}	5.44 ± 0.98^{ab}	5.52 ± 0.14^{a}	5.40 ± 0.38^{a}	5.80 ± 0.92^{a}	5.76 ± 0.11^{ab}
BNS	4.68 ± 0.82^{a}	4.86 ± 0.76^{a}	4.68 ± 0.73^{a}	5.16 ± 0.91^{a}	4.64 ± 0.09^{a}	5.20 ± 0.45^{a}	4.84 ± 0.15^{a}

Values are means of 25-member panel scores
Means within the same column with different superscripts are significantly different ($p<0.05$)
BXY=0% Fermented Finger Millet Flour (FFMF) Substitution, BTU=5% FFMF Substitution, BMW=10% FFMF Substitution, BZQ=15% FFMF Substitution, BNS=20% FFMF Substitution

Table 8. Sensory Scores of Bread Samples from 48 h Fermented Finger Millet Flour

Sample	Crust Colour	Crumb Colour	Aroma	Texture	Taste	Mouth Feel	Overall Acceptability
CXY	7.80 ± 0.61^{c}	7.88 ± 0.51^{c}	7.64 ± 0.04^{b}	7.72 ± 0.17^{c}	7.40 ± 0.32^{b}	7.44 ± 0.29^{b}	8.24 ± 0.78^{c}
CTU	6.44 ± 0.50^{b}	7.21 ± 0.40^{c}	7.04 ± 0.37^{ab}	6.88 ± 0.27^{bc}	6.68 ± 0.55^{ab}	6.24 ± 0.07^{a}	6.84 ± 0.18^{b}
CMW	5.76 ± 0.81^{ab}	6.40 ± 0.72^{b}	6.08 ± 0.06^{a}	6.60 ± 0.83^{ab}	6.36 ± 0.78^{ab}	6.12 ± 0.07^{a}	6.76 ± 0.74^{b}
CZQ	5.52 ± 0.06^{ab}	5.72 ± 0.04^{ab}	6.04 ± 0.13^{a}	6.20 ± 0.26^{ab}	6.12 ± 0.90^{a}	5.56 ± 0.15^{a}	6.32 ± 0.06^{ab}
CNS	5.32 ± 0.93^{a}	5.23 ± 0.88^{a}	6.00 ± 0.96^{a}	5.84 ± 0.01^{a}	5.84 ± 0.39^{a}	5.52 ± 0.16^{a}	5.56 ± 0.16^{a}

Values are means of 25-member panel scores
Means within the same column with different superscripts are significantly different ($p<0.05$)
CXY=0% Fermented Finger Millet Flour (FFMF) Substitution, CTU=5% FFMF Substitution, CMW=10% FFMF Substitution, CZQ=15% FFMF Substitution, CNS=20% FFMF Substitution

Table 9. Sensory Scores of Bread Samples from 72 h Fermented Finger Millet Flour

Sample	Crust Colour	Crumb Colour	Aroma	Texture	Taste	Mouth Feel	Overall Acceptability
DXY	7.88 ± 0.13^{c}	7.40 ± 0.12^{c}	7.44 ± 0.23^{c}	7.28 ± 0.94^{b}	6.92 ± 0.61^{a}	7.16 ± 0.43^{b}	8.08 ± 0.15^{b}
DTU	6.84 ± 0.21^{b}	6.44 ± 0.22^{b}	6.64 ± 0.38^{b}	6.88 ± 0.97^{ab}	6.68 ± 0.77^{a}	6.56 ± 0.61^{ab}	7.00 ± 0.44^{a}
DMW	6.12 ± 0.01^{ab}	6.00 ± 0.02^{b}	6.60 ± 0.29^{b}	6.60 ± 0.50^{ab}	6.28 ± 0.51^{a}	6.52 ± 0.78^{ab}	6.88 ± 0.36^{a}
DZQ	6.00 ± 0.38^{ab}	5.92 ± 0.28^{ab}	6.44 ± 0.42^{ab}	6.28 ± 0.46^{a}	6.20 ± 0.66^{a}	6.32 ± 0.60^{ab}	6.80 ± 0.44^{a}
DNS	5.36 ± 0.04^{a}	5.53 ± 0.05^{a}	5.68 ± 0.55^{a}	6.12 ± 0.54^{a}	5.96 ± 0.62^{a}	6.08 ± 0.71^{a}	6.48 ± 0.78^{a}

Values are means of 25-member panel scores
Means within the same column with different superscripts are significantly different ($p<0.05$)
DXY=0% Fermented Finger Millet Flour (FFMF) Substitution, DTU=5% FFMF Substitution, DMW=10% FFMF Substitution, DZQ=15% FFMF Substitution, DNS=20% FFMF Substitution

The results of evaluation of crust colour, showed no significant difference (p<0.05) between the 5% FMF substitution bread sample and the control, but the other composite bread samples were significantly different (p<0.05) from the control (Table 6), while the results of evaluation of crust colour showed significant difference (p<0.05) in the composite bread samples and the control (Tables 7, 8, and 9). It is evident from the results that the 100% wheat flour breads had the highest score (7.48, 7.80, and 7.88) for crust colour followed by bread prepared from 95% wheat and 5% FFMF combination (6.60, 6.44, and 6.84) (Tables 7, 8, and 9) respectively. From the results, crumb colour ranged from 4.42 to 7.62, 4.86 to 7.50, 5.23 to 7.88, and 5.63 to 7.40, with control having the highest score (7.62, 7.50, 7.88, and 7.40), followed by bread containing 5% FFMF (6.40, 6.80, 7.21, and 6.44), and the least scored was bread containing 20% FFMF (Tables 6, 7, 8, and 9) respectively. The composite bread sample containing 5% FFMF was observed to be significantly the same (p<0.05) with the control bread for crumb colour (Table 6, 7, and 8). Quality scores for aroma of the breads ranged from 5.60 to 7.04, 4.68 to 6.40, 6.00 to 7.64, and 5.68 to 7.44 (Tables 6, 7, 8, and 9) respectively. It can be observed from the results obtained that there was no significant difference (p<0.05) between the 5% FFMF substitution bread sample and the control bread (Table 7), while other composite bread samples i.e. 10%, 15% and 20% FFMF substitutions were significantly different (p<0.05) from the control (Tables 6, 7, 8, and 9) respectively. The 100% wheat bread was rated highest (7.64 and 7.44) followed by bread prepared from 5% FM flour substitution (7.04 and 6.64), and the lowest score was observed from 20:80% FFMF to wheat flour combination bread sample (6.00 and 5.68) (Tables 8 and 9) respectively. The texture was significantly affected with increase in the level of FM flour substitution (Tables 6, 7, 8, and 9). There was significant difference (p<0.05) between the composite bread samples and the control in the case of texture (Tables 6 and 9). The 100% wheat flour bread had the highest score (6.96, 7.72 and 7.28) and the lowest was obtained in 20% FFMF substitution bread (5.16, 5.82 and 6.12) (Tables 7, 8, and 9) respectively. From the results, bread prepared from 5% FFMF substitution was not significantly different (p<0.05) from that of 100% wheat flour, but other composite breads were significantly different (p<0.05) from the control for texture (Table 7). There was a significant difference (p<0.05) observed between the composite breads and the control (Table 8). The supplementation of FMF into wheat bread resulted in significant reduction in taste scores for all the bread samples produced. From the results, the 100% wheat flour bread was scored significantly (p<0.05) highest (6.56, 6.72, 7.40, and 6.92) followed by bread prepared from 5% FM substitution (6.12, 5.84, 6.68, and 6.68), while bread with 20% FM had the lowest value (5.48, 4.64, 5.84, and 5.96) (Tables 6, 7, 8, and 9) respectively. The composite breads were significantly different (p<0.05) from the control for taste (Tables 6, 7, 8). Meanwhile, the composite breads were not significantly different (p<0.05) from the control for taste (Table 9). The mouth feel was also slightly affected as the level of FMF substitution rises. From the results, quality scores for mouth feel of the breads ranged from 5.28 to 6.20, 5.20 to 6.36, 5.52 to 7.44, and 6.08 to 7.16 (Tables 6, 7, 8, and 9) respectively. The highest (6.20, 6.36, 7.44, and 7.16) significant value (p<0.05) for the quality score of 100% wheat flour prepared breads followed by bread prepared from 5% FM substitution (6.00, 6.16, 6.24, and 6.56), while bread prepared from 20% FM flour gave the lowest score (5.28, 5.20, 5.52, and 6.08) (Table 6, 7, 8, and 9) respectively. Though, the composite breads were not significantly different (p<0.05) from the control breads (Table 6, 7, 8). All the composite bread samples were significantly the same but different significantly (p<0.05) from the control bread (Table 8). The composite breads were all significantly different (p<0.05) from the control bread (Table 9). The results indicated that the overall acceptability of the bread samples were significantly affected by level of supplementation for all bread samples (Tables 6,7,8 and 9). The 100% wheat bread had maximum score (6.52, 7.24, 8.24, and 8.08) compared to score (6.48, 6.56, 6.84, and 7.00) recorded for the bread prepared with 95:5% wheat flour to FM flour combination, and the lowest was obtained from 80:20% wheat flour to finger millet flour combination (5.68, 4.84, 5.56, and 6.48) (Table 6, 7, 8, and 9) respectively. There was no significant difference (p<0.05) between the composite bread samples and the control (Table 6). All the composite bread samples were observed to be significantly different (p<0.05) from the control (100% wheat flour bread) (Tables 7,8). The composite breads were all significantly the same (p<0.05), but different significantly (p<0.05) from the control bread (Table 9).

In this research generally, it was observed that the sensory properties of all the bread samples prepared from unfermented finger millet flour, 24 h, 48 h and 72 h fermented finger millet flour with wheat flour combinations were significantly affected as the level of incorporation of finger millet flour increased. From the results in Tables 6, 7, 8, and 9, it is obvious that the 100% wheat breads had the highest score, followed by breads made from 95:5% wheat flour to FMF combination, while bread samples with 20% finger millet flour were least rated for all the sensory attributes tested. As the level of incorporation of FMF increased, darkness in the crust colour of the composite bread samples were observed which might have been imparted by the FM flour. Claughton and Pearce [16] also observed similar colour effect (darkness) when different levels of sunflour protein isolate were blended with wheat flour for biscuit production. Crust colour is a very essential parameter in judging properly baked bread that not only reflect how suitable are the raw materials used for the production but also gives knowledge about the formation and quality of the product. The texture was significantly affected with rise in the level of FMF substitution. The texture became harder as the FM flour substitution was increased. This increase in texture is due to low carbon dioxide gas that was retained in the mixed dough, which could result in dense texture bread [14]. This is due to dilution effects of gluten (which traps the carbon dioxide gas generated by yeast during fermentation) with blending of non-wheat flour such as FM flour as it contains high fibre content [17]. The supplementation of FMF into wheat bread resulted in significant reduction in taste scores. This is attributed to the bitter taste of some inherent compounds in FM flour particularly at high temperature as reported by Ayo *et al.* [18], in the production of breads from wheat and black sesame flour at different level combinations. The mouth feel was also significantly affected as the level of FMF substitution rises. The baking conditions (temperature and time variables); the state of the bread components, such as fibre, starch, protein (gluten) whether undamaged or damaged and the amounts of absorbed water during dough mixing, all contribute to the final mouth feel of the bread [19]. The results indicated that the overall acceptability of the bread samples were significantly affected by level of supplementation. In general, the baking properties of composite flour and the organoleptic attributes of its products, are often impaired or affected due to the dilution of the gluten content [20]. From the results, it is obvious that the 100% wheat bread had the highest score followed by breads made from 95:5% wheat flour to FMF combinations. Breads prepared from higher level of supplementation with FM flour (90:10, 85:15 and 80:20% wheat flour to FM Flour combinations) were fairly rated by panelists with respect to all the sensory properties. Bread samples prepared with different proportion of unfermented FMF, 24 h, 48 h and 72 h FFMF to wheat flour combinations are shown in Plates 1, 2, 3, and 4 respectively.


AXY


ATU


AMW


AZQ


ANS

Plate 1. Bread Samples Incorporated with Different Proportion of Unfermented Finger Millet Flour

AXY=0% Unfermented Finger Millet Flour (UFMF) Substitution (Control), ATU=5% UFMF Substitution, AMW=10% UFMF Substitution, AZQ=15% UFMF Substitution, ANS=20% UFMF Substitution

BXY **BTU** **BMW**

BZQ **BNS**

Plate 2. Bread Samples Incorporated with Different Proportion of 24 h Fermented Finger Millet Flour

BXY=0% Fermented Finger Millet Flour (FFMF) Substitution (Control), BTU=5% FFMF Substitution, BMW=10% FFMF Substitution, BZQ=15% FFMF Substitution, BNS=20% FFMF Substitution

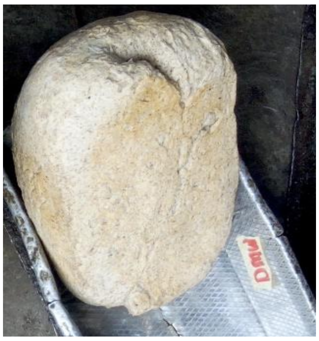
CXY **CTU** **CMW**

CZQ **CNS**

Plate 3. Bread Samples Incorporated with Different Proportion of 48 h Fermented Finger Millet Flour

CXY=0% Fermented Finger Millet Flour (FFMF) Substitution, CTU=5% FFMF Substitution, CMW=10% FFMF Substitution, CZQ=15% FFMF Substitution, CNS=20% FFMF Substitution



DXY **DTU** **DMW**

DZQ **DNS**

Plate 4. Bread Samples Incorporated with Different Proportion of 72 h Fermented Finger Millet Flour

DXY=0% Fermented Finger Millet Flour (FFMF) Substitution, DTU=5% FFMF Substitution, DMW=10% FFMF Substitution, DZQ=15% FFMF Substitution, DNS=20% FFMF Substitution

4. CONCLUSION

Based on the findings of this study, physical and sensory properties of bread made from fermented FM flour and wheat flour blends at 5:95, 10:90, 15:85 and 20:80% combinations respectively, showed that the flour generated from this pretreatment method (fermentation) has potentials in bread production and other food product formulations. Due to absence of gluten protein in FM flour, use of FM flour in white bread was limited to 20% considering acceptable physical and sensory quality. However, supplementation of wheat flour with FM flour significantly affected loaf volume, specific volume as well as the oven spring but added to the loaf weight. Fermentation period of 24 and 48 h, and substitution of 5 and 10% FFMF into wheat gave the breads with the best overall sensory acceptability. This research therefore provided knowledge on the best fermentation period and level of substitution of FM in bread production and other bakery products. White bread enriched with FM flour contains higher crude fiber and calcium as compared to white bread and thus can be a healthy option for the people doing weight management and for the prevention of constipation and colon cancer.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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