Physical Properties and Mineral Content of Bread Produced from Wheat, Malted Mung Bean, and Watermelon Rind Flour Composites

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KEYWORDS

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ABSTRACT

This study was carried out to evaluate the physical properties and mineral content of breads produced from of wheat, malted mung bean and watermelon rind composite flours. Mung bean seeds were soaked for 24 h, washed, drained, germinated for 72 h, oven-dried in a tray dryer (Model EU850D, UK) at 60oC for 18 h occasionally stirring grains at intervals of 30 min and then milled into flour. The watermelon rind was sliced, washed, oven-dried and milled into flour and then sieved. Both flours were blended with wheat flour in varying proportions (100:0; 90:5: 5; 80:10:10; 70:15:15; 60:20:20 and 50:25:25) to produce bread. The physical properties and mineral content and of the bread samples were determined using standard methods. The physical properties of the bread samples showed that the loaf volume, specific volume, height, and oven spring decreased, while the weight increased significantly (p<0.05) with increased substitution of mung bean and watermelon rind flours. The study, therefore, showed that the mineral contents and the weight of the bread samples could be enhanced by the addition of mung bean and watermelon rind flours to wheat flour at different substitution levels in the production of bread samples. The mineral composition of the bread loaves were calcium (77.01-97.77), magnesium (48.89-114.74), phosphorous (41.11-97.76), potassium (62.67-94.21), iron (2.18-2.78), while sodium content ranged from 1.62 to 2.25mg/100g. The result showed that the bread loaves produced from the composite flours increased in weight and all the minerals evaluated with an increase in the substitution of malted mung bean and watermelon rind flours.

INTRODUCTION

Bread, a staple food worldwide, is commonly produced using wheat flour as its primary ingredient due to its unique gluten-forming ability that provides the necessary structure and texture (Umego *et al.,* 2010). However, there is growing interest in composite flours which blend wheat flour with other plant based flours to enhance the nutritional profile and diversify bread products (Akoja and Cooker 2010).

The incorporation of flours from legumes (mung beans, cowpea, etc.) or root crops as well as the inclusion of fruits and vegetables to wheat flours can improve the mineral content, dietary fiber, and overall health benefits of bread (Egbujie *et al.,* 2021).

Mung beans (*Vigna radiata*) are recognized for their high nutritive value, containing substantial amounts of protein, vitamins, and minerals (Umego *et al.*, 2010). Mung beans (Vigna radiata) are excellent sources of protein, dietary fiber, minerals, vitamins, and significant quantity of bioactive compounds, which include polyphenols, polysaccharides, and peptides, this makes it a popular functional legume to promote good health. There is literature evidence that reports that the consumption of mung bean can ameliorate hyperglycemia, hyperlipemia, and hypertension, and prevent cancer and melanogenesis. This is because mung bean possess hepatoprotective and immunomodulatory activities (Hou *et al*., 2019).

Malting mung beans can further enhance their nutritional properties and digestibility, making them a valuable addition to composite flours (Umego *et al.*, 2010). Although mung beans are rich in proteins and minerals, they are deficient in dietary fibre, and contains less vitamins compared to fruits. Therefore, watermelon rind flour, derived from the often-discarded rind of watermelons, presents a sustainable and nutritious option. It is rich in protein, vitamins, minerals, and dietary fiber, offering a means to reduce food waste while improving the nutritional content of bread.

This study aims to evaluate some of the physical properties and mineral of bread produced from wheat, malted mung bean, and watermelon composite flours. By combining these ingredients, the resulting bread is expected to exhibit improved nutritional value and acceptable physical characteristics, contributing to the development of healthier and more sustainable bread-making practices (Abu *et al*., 2021).

MATERIALS AND METHODS

Sources of Materials

Mung bean seeds and watermelon fruit (*Citrullus lanatus*) used for the study were bought from New Market Enugu, Enugu State, Nigeria. The wheat flour and other ingredients such as bakery fat, sugar, yeast, salt and flavourant were purchased from recognized dealers in the same market.

Experimental Design

A partial substitution design was adopted for this study. In this design, the wheat, mung bean and watermelon rind flours were blended together at different ratios and used to produce five different samples of bread with the sample produced from 100% wheat flour used as control.

Table 1: The Design Table for Composite Blends

Flour Samples	Unit	Minimum	Maximum
Wheat flour	g	50	100
Mung bean flour	g	0	25
Watermelon rind flour	g	0	25

Experimental Design

A Partial Substitution Design was used.

Table 2: Flour blends used for bread production

Samples	Wheat flour	Mung bean flour	Watermelon rind flour
A	100	0	0
B	90	5	5
C	80	10	10
D	70	15	15
E	60	20	20
F	50	25	25

Mung Bean Flour Preparation

The malted mung bean flour was prepared according to the method described by Onwurafor *et al.* (2019). One kilogramme (1kg) of mung bean seeds were cleaned to remove dirt and other extraneous materials. The cleaned seeds were soaked in 4 l of potable water in a plastic bowl at room temperature (30± 2ºC) for 20 h with a change of water at every 5 h to prevent fermentation. After soaking, the grains were drained, rinsed and immersed in 2% Sodium hypochlorite solution for 10 min to disinfect the grains. The seeds were rinsed for five consecutive times with excess water and cast on a moistened jute bag, covered with polyethylene bag and left for 48 h to fasten sprouting. The grains were then spread carefully on the jute bag and allowed to germinate for 72 h and then dried in a tray dryer (Model EU850D, UK) at 60ºC for 18 h. The dried malted mung bean seeds were milled in the attrition mill and sieved through a 500-micron mesh sieve. The flour produced was packaged in an air tight plastic container, labelled and stored in a refrigerator until needed for further use.

Watermelon Rind Flour Preparation

The watermelon rind flour was prepared according to the method described by Oseni *et al*. (2013). The cleaned watermelon rinds were sliced into smaller slices of 5 mm in diameter with a stainless steel knife. The slices were dried in a tray dryer (Model EU850D, UK) at 50ºC for 18 h to obtain dried chips The chips were milled in the attrition mill and sieved through a 500-micron mesh sieve to obtain the fine flour. The flour produced was packaged in an air-tight plastic container, labelled and stored in the refrigerator until needed for further use.

Formulation of Composite Flour

The wheat, mung bean and watermelon rind flours were blended in the ratios of 100:0:0, 90:5:5, 80:10:10, 70:15:15, 60:20:20 and 50:25:25 in a Ken wood mixer (Model Philips, type HR, 1500/ A, Holland) to obtain homogenous samples of composite flour. Thereafter, the flour blends were individually packaged in air tight plastic containers, labelled and kept in a desiccator until needed for the production of bread loaves.

Bread Production

The bread loaves were prepared according to the method described by Akoja *et al.* (2010). The recipe used for the preparation of breads contained 100% flour, 60% sugar, 20% fat, 2% yeast, 2.5 mL vanilla flavour, 5% milk, 0.25% salt. All the raw materials were thoroughly mixed together manually to obtain homogeneous mixtures and kneaded properly on a flour dusty table (to avoid sticky) to incorporate air into the dough. The milled dough was weighed to obtain accurate and uniform measurements and thereafter, the weighed dough was moulded into shape, placed in a greased pan and then proofed. The fermented dough was baked in a convention oven (Mac Adams Rotary Oven, South Africa) at 200ºC for 20 min. After baking, the baked bread loaves were removed from oven, depanned and allowed to cool at ambient room temperature. The cooled breads were, packaged in aluminum foil wraps, labelled and kept in a desiccator until needed for laboratory analysis.

Determination of Physical Properties of the Bread Samples

The loaf volume, specific volume, weight, height, and oven spring were determined according to AOAC (2010) method.

Determination of Mineral Composition

The calcium, magnesium, phosphorus, potassium, iron, and sodium contents of the bread samples were determined according to AOAC (2010) method.

Statistical Analysis:

The data generated was subjected to One-way Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS, Version 20) software. Means were separated using Turkey's least significant difference (LSD) test at $p<0.05$.

RESULTS AND DISCUSSION

Physical Properties of the Bread Samples

The physical properties of the bread samples are presented in Table 1. The Loaf volume of the bread samples ranged from 3.10 to 15.5cm^3. The control (100% wheat flour bread) had the highest values (15.5cm^3) while the sample substituted with 25% mung bean and 25% watermelon rind flours had the least value (3.10 cm^3). The decrease could be due to the addition of high amounts of mung bean and watermelon rind flour to the sample. The result is in agreement with the findings of Dabels *et al.* (2016) who reported a reduction in loaf volume of bread as the level of addition of non-wheat flour increased.

Table 1: Physical properties of bread samples

Samples	% Substitution WF: MMBF:WRF	Loaf Volume (cm^3)	Specific Volume (cm^3)	Weight (g)	Height (m^2)	Oven Spring (m^2)
A	100:0:0	15.5^a±0.71	5.40^a±0.00	295.00^f±0.00	10.20^a±0.01	2.70^a±0.01
B	90:5:5	14.05^b±0.07	4.70^b±0.01	296.50^e±0.71	8.19^b±0.01	2.40^b±0.00
C	80:10:10	12.0^c±0.04	3.31^c±0.01	298.01^d±0.01	6.95^c±0.01	2.00^c±0.00
D	70:15:15	10.00^d±0.00	3.31^c±0.01	300.00^c±0.00	5.50^d±0.00	1.50^d±0.00
E	60:20:20	6.10^e±0.01	2.30^d±0.01	302.50^b±0.71	4.00^e±0.00	1.30^e±0.01
F	50:25:25	3.10^f±0.01	1.30^e±0.01	306.00^a±0.71	2.98^f±0.04	1.10^f±0.00

Data are mean ± standard deviation of triplicate determinations. Means in the same column bearing different superscripts differed significantly (p<0.05) from each other. A: Bread made from 100% wheat flour, B: Bread made from 90% wheat flour , 5% malted mung bean flour and 5% watermelon rind flour, C: Bread made from 80% wheat flour, 10% malted mung bean flour and 10% watermelon rind flour, D: Bread made from 70% wheat flour, 15% malted mung bean flour and 15% watermelon rind flour, E: Bread made from 60% wheat flour, 20% malted mung bean flour and 20% watermelon rind flour, F: Bread made from 50% wheat flour, 25% malted mung bean flour and 25% watermelon rind flour. WF — Wheat flour, MPPF — Malted mung bean flour, WRF — Watermelon rind flour.

The specific volume of the bread samples varied between 1.30 and 5.40 cm³ it is observed that significant differences ($p < 0.05$) existed among the samples. Notably, the specific volume range (1.30 – 5.40 cm³) was higher than the values reported by Zhang and Datta (2016) for bread made from cassava and wheat composite flours, which ranged from 1.56 to 3.24 cm³.

The weight of the bread samples ranged from 294.00 to 306.00g. There was significant ($p<0.05$) difference in weight among the samples. The weight of the bread samples increased as the level of substitution with mung bean and watermelon rind flours increased. The increase could be due to the fact that mung bean and watermelon rind flours contain high amount of fibre which has the ability to retain moisture which in turn contributes to the weight of the composite breads (Zhang and Datta, 2016).

The height of the bread samples ranged from 2.98 to 10.20 m^2. There were significant ($p<0.05$) differences in height among the samples. The height of the bread samples decreased as the level of substitution of mung bean and watermelon rind flours increased in the products. The result showed that the samples substituted with higher proportion of mung bean and watermelon rind flour had the lower values for height compared to the control sample. Zhang and Datta, (2016) reported that the height of the bread loaf is primarily affected by the volumetric expansion of the dough due to gas evolution during proofing coupled with the onset of gelatinization which causes faster plasticization of the starch-protein network on the gas cell wall formed.

The oven spring of the bread samples ranged from 1.10 to 2.70 m^2. There were significant ($p<0.05$) differences in oven spring among the samples. The sample substituted with 25% mung bean and 25% watermelon rind flours had the least value (1.10m^2), while the control sample (100% wheat flour bread) had the highest value (2.70m^2). This might be as a result of substitution effect as retailers and consumers prefer bread such are large and substantial, making it visually appealing. The values (1.10 – 2.70 m^2) obtained in this study were lower than the oven spring (2.26 – 3.58m^2) reported by Bridgewater and Beatrice (2016) for bread produced from cassava and wheat composite flours. Oven spring is the difference between the height of the dough after proofing and the height of loaf after baking.

Generally, the addition of malted mung bean and watermelon rind flours to wheat flour in the production of bread loaves greatly decreased the loaf volume, height and oven spring with remarkable increase in the weight of the products.

Mineral Composition of Bread Samples

The Calcium content of the samples ranged from 77.01 to 97.77 mg/100g. The observed increase in calcium content of all the samples of composite bread samples could be attributed to increase in the addition of malted mung bean and watermelon rind lour in the samples which is an indication that mung bean and watermelon rind are good sources of calcium (Onwurafor *et al.,* 2019; Imosi *et al.,* 2020).

Table 2 Mineral composition (mg/ 100g) of bread samples

Samples	% Substitution WF: MMBF: WRF	Calcium	Magnesium	Phosphorus	Potassium	Iron	Sodium
A	100:0:0	$77.01^{f}\pm0.75$	$48.89^{f}\pm0.47$	$41.11^{f}\pm0.69$	$62.67^{f}\pm0.01$	$2.18^{f}\pm0.01$	$1.62^{f}\pm0.01$
B	90:5:5	$82.04^{e}\pm0.70$	$53.92^{e}\pm0.69$	$58.69^{e}\pm0.71$	$68.05^{e}\pm0.70$	$2.29^{e}\pm0.01$	$1.66^{e}\pm0.01$
C	80:10:10	$86.91^{d}\pm0.71$	$67.95^{d}\pm0.72$	$66.34^{d}\pm0.69$	$73.45^{d}\pm0.01$	$2.35^{d}\pm0.01$	$1.75^{d}\pm0.01$
D	70:15:15	$87.22^{c}\pm0.62$	$81.33^{c}\pm0.69$	$73.33^{c}\pm0.71$	$79.33^{c}\pm0.55$	$2.48^{c}\pm0.01$	$1.83^{c}\pm0.01$
E	60:20:20	$91.77^{b}\pm0.73$	$95.37^{b}\pm1.44$	$89.37^{b}\pm0.57$	$86.74^{b}\pm0.69$	$2.65^{b}\pm0.01$	$1.97^{b}\pm0.01$
F	50:25:25	$97.77^{a}\pm0.72$	$114.74^{a}\pm0.73$	$97.76^{a}\pm1.27$	$94.21^{a}\pm1.32$	$2.78^{a}\pm0.01$	$2.25^{a}\pm0.01$

Data are mean ± standard deviation of triplicate determinations. Means in the same column bearing different superscripts differed significantly (p<0.05) from each other. A: Bread made from 100% wheat flour, B: Bread made from 90% wheat flour, 5% malted mung bean flour and 5% watermelon rind flour, C: bread made from 80% wheat flour, 10% malted mung bean flour and 10% watermelon rind flour, D: bread made from 70% wheat flour, 15% malted mung bean flour and 15% watermelon rind flour, E: bread made from 60% wheat flour, 20% malted mung bean flour and 20% watermelon rind flour, F: bread made from 50% wheat flour, 25% malted mung bean flour and 25% watermelon rind flour. WF — Wheat flour, MPPF — Malted mung bean flour, WRF — Watermelon rind flour.

The magnesium content of the bread samples ranged from 48.89 to 114.74mg/100g. The sample fortified with 25% malted mung bean and 25% watermelon rind flours had the highest value (114.74mg/100g), while the control (100% wheat flour bread) had the least value (48.89 mg/100g). The increase could be attributed to substitution effect which was an indication that mung bean and watermelon rind are good sources of magnesium (Umego *et al.,* 2010). Magnesium is important for bone formation, control of constipation and management of diabetes (Jacob *et al.,* 2015).

The phosphorus content of the samples ranged from 41.11 to 97.76mg/100g. There were significant ($p<0.05$) differences in phosphorus content among the samples. The variation could be attributed to differences in the proportions of raw materials used for the production of bread samples. The increase in the incorporation of malted mung bean and watermelon rind flour in the preparation of bread samples resulted in increase in their phosphorus contents. Phosphorus helps in healthy bone formation, improvement of digestion, regulation of excretion and protein formation in human body. It also enhances the quick release of energy in the body (Okaka *et al.,* 2006).

The potassium content of the bread samples increased significantly ($p < 0.05$) with higher substitution levels of malted mung bean flour (MMBF) and watermelon rind flour (WRF). Sample A, made from 100% wheat flour, had the lowest potassium content (62.67 ± 0.01 mg/100 g), while Sample F, with 50% wheat flour, 25% MMBF, and 25% WRF, had the highest potassium content (94.21 ± 1.32 mg/100 g). This trend suggests that the inclusion of MMBF and WRF enhances the potassium content of the bread.

This finding is consistent with studies such as the one by Ramashia *et al*. (2024), which reported that composite flours made from legumes and other plant-based ingredients significantly increase the mineral content, including potassium, in baked products. Similarly, a study on sweet potato-wheat composite bread found that potassium levels ranged from 162.42 to 388.75 mg/100 g, depending on the level of substitution with sweet potato flour (Oluwalana *et al.,* 2012). These results confirm that composite flours are effective in improving the nutritional profile of bread, particularly its potassium content.

The iron content of the bread samples increased significantly ($p < 0.05$) as the substitution levels of malted mung bean flour (MMBF) and watermelon rind flour (WRF) increased. Sample A, made entirely from wheat flour (WF), had the lowest iron content (2.18 ± 0.01 mg/100 g), while Sample F, with 50% WF, 25% MMBF, and 25% WRF, had the highest iron content (2.78 ± 0.01 mg/100 g). This trend indicates that incorporating MMBF and WRF into the composite flour enhances the iron content of the bread.

This finding aligns with studies like Kasapila *et al.* (2024), which demonstrated that substituting wheat flour with biofortified bean puree significantly improved the iron content of bread, reaching an average of 2.04 ± 0.03 mg/100 g in composite samples compared to traditional wheat bread (Ramashia *et al.*, 2024). Similarly, other studies on composite flours, such as those using baobab pulp flour, have shown high mineral contents, including iron, further supporting the trend that composite flours enhance nutritional quality (Dossa *et al.*, 2023).

The sodium content of the bread samples ranged from 1.62 to 1.97mg/100g. There were significant ($p<0.05$) differences in sodium content among the samples. The differences could be due to variation in the proportion of raw materials used for the production of the bread samples. The samples with highest proportions of mung bean and watermelon rind flours had the highest sodium content compared to the control sample. Sodium is an essential element for human growth and prevention of high blood pressure. Generally, the addition of mung bean and watermelon rind flours to wheat flour in the production of breads greatly enhanced the mineral contents of the products.

CONCLUSION

The study showed that the substitution of wheat flour with mung bean and watermelon rind flours in the production of bread improved the nutrient content of the product. From the findings, it was observed that the mineral content of the samples such as calcium, magnesium, phosphorus, potassium, iron, sodium, increased with increased addition of mung bean and watermelon rind flours to the products.

The physical properties of the bread samples showed that loaf volume, specific volume, height and oven spring of the samples decreased with increased addition of mung bean and watermelon rind flours to the products with a remarkable increase in weight of the bread sample.

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