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Physicochemical characteristics of bread partially substituted with finger millet (*Eleusine corocana*) flour

*Características físico-químicas de pão parcialmente substituído por farinha de milheto (*Eleusine coracana*)*

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Abstract

Finger millet (*Eleusine corocana*) is a staple cereal grain available in most parts of Africa and India but it is an underutilized and neglected product. It has a low-glycemic index with some nutraceutical advantages. This study aimed to determine the physicochemical characteristics of bread made from wheat and finger millet (FM) composite flours. Wheat flour was blended with FM flour at 10%, 20%, 30% and 40% levels for bread production. Functional properties, pH of composite flours, physical properties and proximate composition of bread were determined. Water and oil holding capacity of flour blends increased from 130.61 to 135.06 and 120.55 to 125.43 g/g, respectively. However, packed and loose bulk density and emulsion stability decreased with inclusion level of FM flour. The pH values of flour blends increased from 5.88 to 6.11. The total color difference of composite bread in terms of crumb and crust increased with the addition of FM flour. Proximate composition of composite bread revealed decrease in moisture and protein contents and increase in ash, fiber, fat contents and carbohydrate at $p < 0.05$. Incorporation of FM flour decreased the volume and specific volume of bread from 400 to 256.67 mL and 2.69 to 1.81. mL/g, respectively. However, the weight of bread increased from 141.77 to 148.52 g.

Keywords: Finger millet; Wheat; Composite flour; Bread; Functional and physical properties.

Resumo

O milheto (*Eleusine coracana*) é um grão de cereal básico na maior parte da África e da Índia, mas é uma cultura subutilizada e negligenciada. Possui baixo índice glicêmico com algumas vantagens nutracêuticas. O objetivo deste estudo foi determinar as características físico-químicas de pães produzidos com farinhas compostas de trigo e milheto. A farinha de trigo foi misturada com a farinha de milheto (FM) nos níveis de 10%, 20%, 30% e 40% para a produção de pão. Foram determinadas as propriedades funcionais, o pH das farinhas compostas, as propriedades físicas e a composição centesimal do pão. A capacidade de retenção de água e óleo das misturas de farinha aumentou de 130,61 para 135,06 e 120,55 para 125,43 g/g, respectivamente. No entanto, a densidade aparente empacotada e solta e a estabilidade da emulsão diminuíram com o nível de inclusão de farinha FM. Os valores de pH das misturas de farinha aumentaram de 5,88 para 6,11. A diferença de cor total do pão composto em termos de miolo e côdea aumentou com a adição da farinha FM. A composição centesimal do pão composto revelou diminuição nos teores de umidade e proteína e aumento nos teores de cinzas, fibras, gordura e carboidratos a $p <$ 0,05. A incorporação da farinha FM diminuiu o volume e o volume específico do pão de 400 para 256,67 mL e 2,69 para 1,81 mL/g, respectivamente. No entanto, o peso do pão aumentou de 141,77 para 148,52 g.

Palavras-chave: Milheto; Trigo; Farinha composta; Pão; Funcional, Propriedades físicas.

1 Introduction

In recent years, the nutritional modification of food products has gained attraction due to increased consumer's interest in healthy food (Shandilya & Sharma, 2017). Bread is an important and mostly consumed staple cereal-based food globally and it contains useful nutrients such as starch, protein, fiber, vitamins, and minerals (Bagdi et al., 2016; Callejo et al., 2016). In addition, bread is receiving a growing interest as a possible functional food due to its great diffusion and consumption (Irakli et al., 2015). However, bread is poor in protein while rich in carbohydrates, with a high glycemic index, which can lead to obesity and susceptibility to diabetes and biliary-tract cancer (Larsson et al., 2016). The consumption of bread in many countries, especially in sub-Saharan Africa is on the rise due to urbanization, but there is a challenge to meet the supply and demand of bread in order to match the eating habit of consumers (Ayele et al., 2017). Therefore, baking industry have a challenge of producing bread with improved nutritional, physicochemical and sensory characteristics due to increased consumer's demand for high quality and healthy bakery products (Mariotti et al., 2014). Physicochemical properties such as color, specific volume and texture affect the quality of bread which could be influenced by other factors, such as type of flour, additives, and other ingredients (Xiao et al., 2016; Dall'Asta et al., 2013). Researchers and baking industry must optimize bread making technology to enhance the quality, taste, texture, and adding some constituents with reasonable bioactive compounds, nutraceutical and functional characteristics so that formulated bread will be accepted by consumers (Dziki et al., 2014).

Wheat, which is a basic ingredient in bread making, contains starches and glutens that favor the baking of leavened aerated bread, but is deficient in fat and balanced amino acids (Goesaert et al., 2005). However, much of the wheat imported with high gluten functionality is not suitable for cultivation in tropical climates. With an increase interest in locally based food ingredients to partially replace wheat flour in bread making, the performance of cassava flour with soybean flour added in wheat bread has been reported (Ayele et al., 2017). Partial substitution of wheat flour with flour from other crops such as root and tuber could be a valuable strategy to overcome shortage of wheat in developing countries due to high price of wheat in the global market (Mitiku et al., 2018). It is therefore imperative to use locally available cheap crops like finger millet (FM) for baking purposes to meet the needs of people consuming wheat bread.

Finger millet (*Eleusine corocana*) is one of the important millets and serves as staple food to millions of economically disadvantaged people in Africa and Asia. It is a rich source of carbohydrate, protein, dietary fiber, vitamins B complex and minerals such as calcium, phosphorus, magnesium, and manganese (Okwudili Udeh et al., 2017). Dietary fiber and mineral content of FM are higher than that of wheat and rice (Ramashia et al., 2018). Finger millet is utilized to produce *roti* or *chapatti* (unleavened flat bread), *mudde* (dumpling) and *ambali* (thin porridge) for human consumption. A previous study has shown that it is possible to incorporate FM flour with wheat flour at different proportions for baking bread, biscuit and snacks (Gavurnikova et al., 2011). Partial replacement of wheat flour with flour from locally grown cereal grains positively influence the iron and calcium content of the composite bread (Oladele & Aina, 2009). Previous studies conducted by Jensen et al. (2015) and Begum et al. (2011), where wheat flour was replaced with 30 and 20% cassava flour, produced acceptable composite bread with small difference when compared to 100% wheat flour bread. Therefore, this study aimed to produce composite bread from wheat and FM flours to enhance its nutrients as well as diversify the utilization of the underutilized crop. The main aim was achieved by determining the functional properties and pH of flour blends and physicochemical characteristics of composite bread.

2 Materials and methods

2.1 Sample collection

Mixed 2 kg of FM grains were purchased from Thohoyandou market, Limpopo Province, South Africa. Foreign materials were removed from the grains by immersion in clean tap water. Wheat flour (Sasko®, 70 g carbohydrates, 4 g dietary fiber, 2 g fat and 12 g protein), sugar (selati®), salt (cerebos®), margarine (Siqalo®, total fat, 50 g per 100 g), water and dry yeast (anchor yeast®) were also used in this study. Chemicals and analytical reagents (Copper sulphate, Codium sulphate, Sodium hydroxide, Boric acid, hydrochloric acid, Trichloroacetic acid) were purchased from Merck, Centurion, South Africa.

2.2 Flour preparation

FM grains were milled into flour using method of Jideani (2005). Briefly, 2 kg of the grains were cleaned in distilled water where foreign objects and sand were removed. The grains were de-hulled traditionally with a mortar and pestle. The FM grains were put into a mortar with a bit of water and pounded until the bran was separated. The de-hulled grains were dried at 50 °C for 24 h using hot air oven dryer (Module 278, Labotech Ecotherm, South Africa). The grains were milled using Retsh ZM 200 ultra-centrifugal mill at 17000 x g for 3 min and passed through a mesh of below 100 µm. Finger millet flour was then packed and sealed in a polythene bag for further analysis.

2.3 Research design

The research was carried out in a completely randomized design. Factor A was wheat flour, while factor B was ratios of substitution, 10%, 20%, 30%, and 40% of FM flours. Based on the prototypes, addition of more than 50% of FM to wheat flour resulted in products with poor physicochemical properties, limiting the utilization of FM by 40%. A Hundred (100) percent wheat flour was used as the positive control. Composite flours were analyzed for functional properties and pH while the bread samples were analyzed for proximate composition, and physical properties.

2.4 Formulation of flour blends

Composite flours were prepared from wheat and FM flours as shown in Table 1. One hundred (100) percent of wheat flour was used as a control. Sample B consisted of 90% wheat flour and 10% FM flour. Sample C consisted of 80% wheat flour and 20% FM flour. Sample D was 70% wheat flour and 30% FM flour. Sample E consisted of 60% wheat flour and 40% FM flour. The blends were thoroughly mixed using a blender to achieve uniform blending (Aboshora et al., 2016).

Table 1. Formulation of composite flours.

Sample	Wheat flour (%)	Finger millet flour (%)
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40

FM = finger millet. Samples: A = 100% wheat flour (control); B = 90% wheat flour, 10% FM flour; C = 80% wheat flour, 20% FM flour; D = 70% wheat flour, 30% FM flour, E = 60% wheat flour, 40% FM flour.

2.5 Baking of wheat-finger millet composite bread

Bread was produced using the straight dough method as reported by Nwosu et al. (2014). All the ingredients (flour, salt, sugar, yeast, and warm water of 37 ± 1 °C were mixed (Table 2). The mixture was kneaded properly until the dough was soft and uniform. The dough was cut and put inside the greased baking pans and covered with muslin cloth for 2 h at temperature of between 34 and 35 °C for fermentation purpose. The dough was baked in an oven (Defy, Model DSS700, Midrand, Gauteng Province, South Africa) for 30 min at 230 °C. The baked bread was immediately removed from the baking pans and allowed to cool at room temperature before packaging in polyethylene bags.

Table 2. Recipe formulation for bread production.

Ingredients	Sample				
	A	B	C	D	E
Wheat flour (g)	100	90	80	70	60
Finger millet flour (g)	0	10	20	30	40
Salt (g)	2	2	2	2	2
Warm water (mL, 37 °C)	15	15	15	15	15
Sugar (g)	6	6	6	6	6
Shortening (g)	4	4	4	4	4
Yeast powder (g)	2	2	2	2	2

FM = finger millet. Samples: A = 100% wheat flour (control); B = 90% wheat flour, 10% FM flour; C = 80% wheat flour, 20% FM flour; D = 70% wheat flour, 30% FM flour, E = 60% wheat flour, 40% FM flour.

2.6 Determination of functional properties of the composite flour

2.6.1 Bulk density

The bulk density (BD) of the flours was measured using method of Amandikwa et al. (2015). About 10 g of flours were weighed and put into 25 mL measuring cylinder and the volume was recorded as a loose volume. The bottom was tapped on a bench until a constant volume was observed. The packed volume was recorded. The loose BD and packed BD were calculated as the ratio of the flour weight to the volume occupied by the flour before and after tapping using Equation 1 below:

$$Density\left(\frac{g}{cm^3}\right)=\frac{Weight\ of\ flour}{Volume\ of\ flour} \quad (1)$$

2.6.2 Water absorption capacity

The method described by Chandra et al. (2015) was used to determine the water/oil absorption capacity and emulsion stability of the different flours. About 0.5 g of the flour was dissolved in 10 mL of distilled water in centrifuge tubes and vortexed for 30 s. The dispersions stayed at room temperature for 30 min, centrifuged at 2000 x g for 25 min using a Model T-8BL Laby ^{TM} centrifuge (Laboratory Instruments, Ambala Cantt, India). The supernatant was filtered with Whatman No 1 filter paper and volume was accurately measured. The difference between initial volumes of distilled water added to the flour and the volume obtained after filtration was determined. The result was reported as g/g of water absorbed per gram of flour (Equation 2).

$$Water\ absorbtion\ capacity=\frac{Amount\ of\ water\ absorbed}{Weight\ of\ sample} \quad (2)$$

2.6.3 Oil absorption capacity

About 1 g of the flour (W0) was weighed into pre-weighed 50 mL centrifuge tubes and thoroughly mixed with 10 mL (V1) of refined pure sunflower oil using a vortex mixer (Heidolph Reax top, Germany). Flours stood for 30 min. The flour-oil mixture was centrifuged at 2000 x g for 20 min using a centrifuge (Universal 320 E Hettich, Germany). Immediately after centrifugation, the supernatant was carefully poured into a 10 mL graduated cylinder, and the volume was recorded (V2). Oil absorption capacity (OAC) was calculated using the following Equation 3:

$$Oil\,absorption\,capacity = \frac{V1 - V2}{W0} \tag{3}$$

2.6.4 Emulsion stability

The method described by Prajapati et al. (2015) was followed to determine the emulsion stability of composite flours with minor modification. Briefly, 1.0 g flour, 10 mL distilled water and 10 mL sunflower oil were mixed in a centrifuge tube. The emulsion was centrifuged at 2000 x g for 5 min. The emulsion stability was estimated after heating the emulsion contained in calibrated centrifuged tube at 80 °C, for 30 min in a water-bath, cooled for 15 min under running tap water and centrifuged at 2000 x g for 15 min. The emulsion stability expressed as percentage was calculated as the ratio of the height of emulsified layer to the total height of the mixture.

2.7 Physicochemical analysis of composite flour

The pH of the flours was measured in a 10% (w/v) dispersion of the samples in distilled water. The suspension was mixed and pH reading was recorded using a Crison digital pH meter (Crison instrument, Midrand, South Africa). The color of the crust and crumb of bread were measured in triplicates using Hunter Lab colorimeter (MiniScan XE Plus) after calibration with white and black tiles. Color readings were expressed by Hunter values for L*, a* and b*. L* indicates lightness and measure black to white (0 to 100); a* indicated hue (H°) on green (-) to red (+) axis and b* indicated H° on blue (-) to yellow (+) axis. The color change (ΔE), H° and Chroma (C*) was calculated using method of Aboshora et al. (2016) using Equations 4, 5 and 6.

$$\Delta E = \sqrt{\left(L^* - L^*c\right)^2 + \left(a^* - a^*c\right)^2 + \left(b^* - b^*c\right)^2} \tag{4}$$

c = control sample

$$Hue\left(H°\right) = \tan^{-1}\left\{\frac{b*}{a*}\right\} \tag{5}$$

$$Chroma = \sqrt{\left(a*\right)^2 + \left(a*\right)^2} \tag{6}$$

2.8 Proximate composition of composite bread

Proximate composition including moisture, ash content, crude protein, crude fiber, crude fat contents were determined using methods of AOAC (Association of Official Analytical Chemist, 2006) 934.01, 923.03, 990.03, 978.10. Carbohydrate content was calculated by subtracting moisture content, crude protein, crude fat, crude fiber and ash content from 100%.

2.9 Physical properties of composite bread

2.9.1 Loaf volume

Loaf volume was measured by the seed displacement method (Bourekoua et al., 2018) with slight modification, millet grains were replaced with rice grains. The volume of the loaf was calculated by difference between V_1 and V_2, whereby V_1 was the volume of rice grains without bread and V_2 was the volume of rice grains and bread.

2.9.2 Bread specific volume

The specific volume of the bread was determined as shown in the Equation 7 below:

$$Specific\ volume\left(\frac{cm^3}{g}\right) = \frac{Loaf\ volume\ of\ bread}{Weight\ of\ bread} \quad (7)$$

2.9.3 Loaf weight

The loaf weight was determined by the average value of a direct measurement of three breads, using a semi-analytical balance.

2.10 Statistical analysis

Data were analyzed in triplicates and conducted using Statistical Package for Social Science (SPSS, IBM, Chicago, USA) software Version 24. The data were subjected to one-way analysis of variance (ANOVA). The significance differences among the means were determined with Duncan's multiple range test at a significance level of $p < 0.05$.

3 Results and discussion

3.1 pH values and functional properties of composite flour

Table 3 shows the results of pH values and functional properties of composite flours. The highest pH value was found on Sample E at 6.02 and the lowest value on Sample A at 5.88. The decreases of pH values indicate good quality composite flour which reduces the microbiological load (Ramashia et al., 2018). Similar results were reported by Soria-Hernández et al. (2015) on pea flour at 6.42. The loose BD decreased with increasing levels of FM flour which varied from 0.45 g/mL (Sample E) to 0.48 g/mL (Sample A). The loose BD values were significantly different ($p < 0.05$) between samples A, B and E. Sample A (100% wheat flour) had the highest value of loose BD, while 60% wheat flour and 40% FM flour (Sample E) had the lowest values for loose BD. The packed BD varied from 0.69 g/mL on sample E to 0.79 g/mL on Sample A. Omah & Okafor (2015) reported similar results of packed BD on wheat and millet-pigeon pea flour which varied from 0.64 to 0.81 g/mL. Packed BD values were significantly different ($p < 0.05$) between samples C, D and E. Low bulk density of flour is a favorable attribute with regards to transport and storage of flour since it can be easily transported and distributed. Water absorption capacity (WAC) of flour is an indication of the amount of water available for gelatinization (Eke-Ejiofor and Oparaodu, 2019). The ability of flour to be absorbed depends on the availability of hydrophilic groups that bind water molecules (Kulkarni et al., 2002). WAC of flours increased with increasing levels of FM flour and it ranged from 130.61 to 135.06 g/g. Sample A had the lowest WAC value of 130.61 g/g while sample E had the highest WAC value of 135.06 g/g. Significant different ($p < 0.05$) were also observed among WAC of flours.

The increase in the WAC has been associated with increase in the amylose leaching and solubility, and loss of starch crystalline structure (Dasa & Binh, 2019). High WAC of flour indicates that the flours may be used in the formulation of different food products such as dough, sausage, processed cheese, and bakery products. High WAC is used in product bulking and consistency of food product. The observed variation in different flours may be due to different protein concentration, their degree of interaction with water and conformational characteristics (Butt & Batool, 2010).

Table 3. Selected functional properties and pH of flour samples for bread production.

Sample	LBD (g/mL)	PBD (g/mL)	WAC (g/g)	OAC (g/g)	ES (%)	pH
A	0.48 ± 0.01^{c}	0.79 ± 0.01^{c}	130.61 ± 0.46^{a}	120.55 ± 0.49^{a}	41.67 ± 0.68^{e}	5.88 ± 0.01^{a}
B	0.47 ± 0.01^{bc}	0.78 ± 0.02^{c}	132.15 ± 0.60^{b}	122.31 ± 0.42^{b}	38.53 ± 0.76^{d}	5.91 ± 0.01^{b}
C	0.46 ± 0.00^{ab}	0.77 ± 0.01^{bc}	132.65 ± 0.19^{bc}	123.58 ± 0.57^{c}	35.80 ± 0.59^{c}	5.95 ± 0.01^{c}
D	0.46 ± 0.01^{ab}	0.75 ± 0.01^{b}	133.34 ± 0.20^{c}	124.55 ± 0.52^{d}	33.00 ± 0.41^{b}	5.98 ± 0.01^{d}
E	0.45 ± 0.01^{a}	0.69 ± 0.02^{a}	135.06 ± 0.58^{d}	125.43 ± 0.11^{e}	30.22 ± 1.05^{a}	6.02 ± 0.01^{e}

Values are mean ± standard deviation, n = 3. Values followed by the same letters in the same columns are not significantly different ($p < 0.05$). FM = finger millet. Samples: A = 100% wheat flour (control); B = 90% wheat flour, 10% FM flour; C = 80% wheat flour, 20% FM flour; D = 70% wheat flour, 30% FM flour, E = 60% wheat flour, 40% FM flour. LBD = loose bulk density; PBD = Pack bulk density; WAC = Water absorption capacity; OAC = Oil absorption capacity; ES = Emulsion stability.

Mbofung et al. (2006) reported that dough from composite flour absorb more water than the one from wheat flour. Similar results of increase in WAC of composite flours were observed by Chandra et al. (2015) and Menon et al. (2015) on cereal-pulse-fruit seed composite flour. Oil absorption capacity (OAC) of the flours increased with increasing levels of FM flour which varied from 120.55 to 125.43 g/g. Sample A recorded the lowest OAC value of 120.55 g/g, while sample E recorded the highest OAC value of 125.43 g/g. The increase in OAC may be caused by the presence of more hydrophobic proteins which shows dominance in binding lipids. The OAC depends on the intrinsic factors such as protein conformation, amino acid and surface polarity or hydrophobicity (Shrestha and Srivastava, 2017). Non-polar amino acid side chains of protein can form hydrophobic interactions with hydrocarbon chains of lipid (Tharise et al., 2014). The composite flours in the present study have the potential of being useful in food structural interaction such as retention of flavor, improved palatability and shelf-life extension in meat and bakery products where the absorption of fat is desirable (Aremu et al., 2007). Similar findings were also observed by Kaushal et al. (2012) on taro (*Colocasia esculenta*), rice (*Oryza sativa*) and pigeon pea (*Cajanus cajan*) flour. The emulsion stability decreased significantly ($p < 0.05$) with increasing substitution of wheat with FM flour. The values ranged from 30.22 (sample E) to 41.67% (sample A). The decrease in emulsion stability of the composite flours could be due to low protein in the FM flour. Zhao et al. (2015) indicated that a decrease in protein concentration can potentially control the rate of adsorption diffusion and high protein concentration acts as an obstruction to adsorption. The mechanism behind emulsion capacity and stability is that proteins can decrease the surface tension of oil droplets while offering electrostatic repulsion on the surface of the oil droplets. Similar result of decrease in emulsion stability of composite flours was reported by Prajapati et al. (2015).

3.2 Color attributes of the crumb and crust of bread samples

The color of bread samples is given in Table 4 and shown in Figure 1. The L* values of bread crumb samples decreased significantly ($p < 0.05$) with increasing levels of FM flour which varied from 74.95 (Sample A) to 46.06 (Sample E). Sample A was white with significantly higher L* values as compared to other bread samples. The decrease in L* value is attributed to the protection of bread crumb from direct heating as well as probably due to partial modification of white color by substituted FM flour. Moreover, the high porosity crumb surface might have resulted in insufficient reflection of brightness which contributed to lower L* crumb values of composite bread. The a* values of bread crumb samples increased significantly ($p < 0.05$) with increasing levels of FM flour which ranged from -1.03 (Sample A) to 8.73 (Sample E), similar observation was also reported by Mariotti et al. (2014) for the crumb of bread added with barley flour. The b* values of bread crumb samples decreased with increasing levels of FM flour which varied from 24.55 (Sample A) to13.38 Sample E). A similar decreasing trend in L* values and increasing trend of a* values in the bread samples was also reported by Ranasalva & Visvanathan (2014) for bread made from fermented pearl millet flour and wheat flour. The C* values were closer to the b* values for crumb and crust bread samples. The positive values in the Hº of the samples indicate that the product does not deviate from the color.

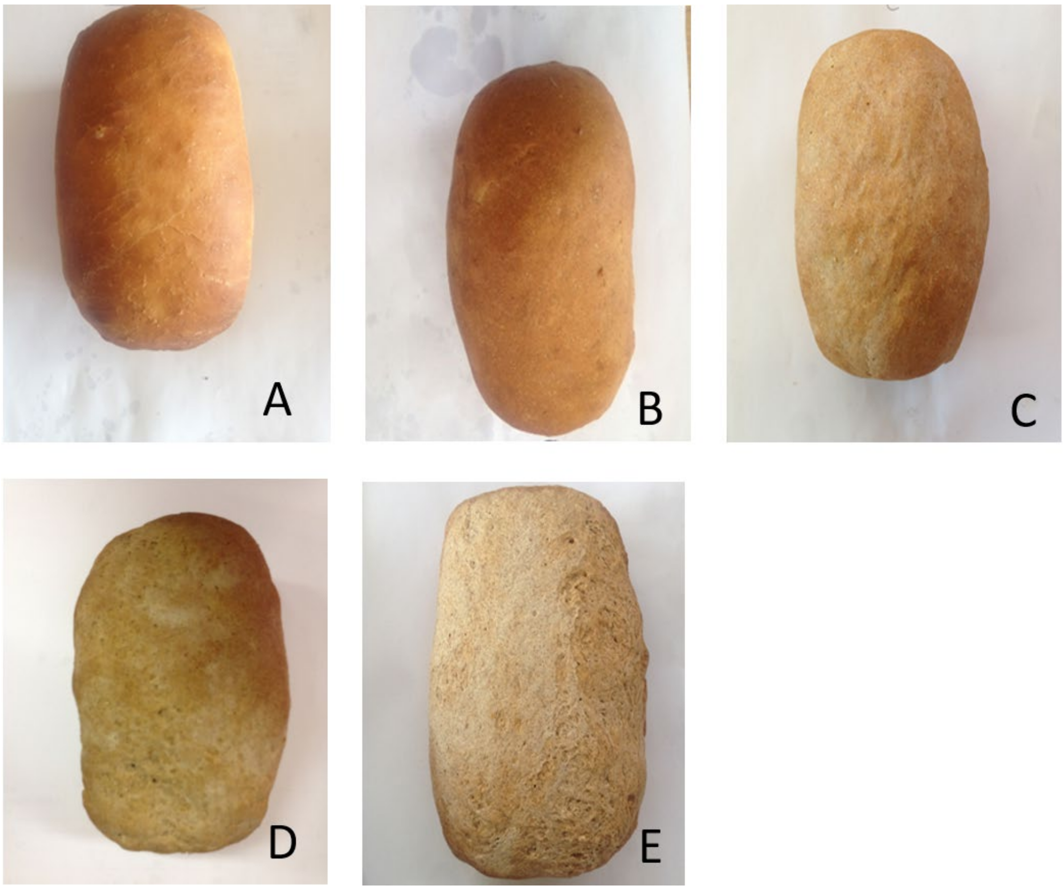

Figure 1. Bread samples prepared from different levels (10% to 40%) of substitution of wheat flour with finger millet (FM) flour. Samples: A = 100% wheat flour (control); B = 90% wheat flour, 10% FM flour; C = 80% wheat flour, 20% FM flour; D = 70% wheat flour, 30% FM flour, E = 60% wheat flour, 40% FM flour.

This adds a positive factor to the current study because lightness and yellowness in the color of the bread are an important factor from a consumer's perceptive. The intensity of C* was higher for sample B in comparison to the intense of C* of sample A (control). Considering crust color, a lower L* value indicated a darker crust, a* parameter indicated crust redness, whereas a higher b* value led to a higher crust yellowness. The L* values for bread crust increased with increasing levels of FM flour ranging from 42.16 (Sample A) to 65.31 (Sample E). Sample A had lower L* values, showing a darker crust than other samples. A similar increasing of L* values for crust color was also observed by Zhu et al. (2016) on Chinese steamed bread. The a* and b* values of crust decreased significantly at $p < 0.05$ with increasing levels of FM flour substitution.

Table 4. Crumb and crust color of bread samples.

Parameters	Bread sample				
	A	B	C	D	E
Crumb color					
L*	74.95 ± 0.81^{e}	64.74 ± 0.22^{d}	56.11 ± 0.51^{c}	53.24 ± 0.51^{b}	46.06 ± 0.88^{a}
a*	-1.03 ± 0.47^{a}	4.64 ± 0.12^{b}	6.30 ± 0.17^{c}	7.23 ± 0.68^{d}	7.73 ± 0.14^{e}
b*	24.55 ± 1.77^{b}	18.20 ± 0.70^{b}	14.71 ± 0.23^{a}	13.91 ± 0.15^{a}	13.38 ± 0.16^{a}
ΔE	-	13.30 ± 0.54^{b}	22.55 ± 0.38^{c}	25.54 ± 0.29^{d}	32.30 ± 0.78^{e}
Hue (H°)	87.54 ± 1.25^{a}	75.67 ± 0.85^{d}	66.17 ± 0.22^{c}	64.36 ± 2.29^{c}	59.60 ± 0.44^{b}
Chroma	24.58 ± 1.75^{d}	18.78 ± 0.65^{c}	16.07 ± 0.28^{b}	14.93 ± 0.42^{ab}	13.98 ± 0.10^{a}
Crust color					
L*	42.16 ± 0.7^{a}	45.37 ± 0.76^{b}	51.27 ± 1.43^{c}	56.25 ± 0.63^{d}	65.31 ± 0.59^{e}
a*	17.48 ± 0.13^{e}	14.55 ± 1.57^{d}	12.31 ± 0.8^{c}	9.77 ± 0.48^{b}	8.04 ± 0.23^{a}
b*	25.05 ± 0.14^{c}	25.77 ± 0.56^{c}	25.44 ± 1.18^{bc}	23.97 ± 0.65^{b}	15.52 ± 0.98^{a}
ΔE	-	4.48 ± 1.56^{b}	10.56 ± 1.24^{c}	16.91 ± 1.89^{d}	27.2 ± 0.52^{e}
Hue (H°)	30.54 ± 0.17^{d}	29.60 ± 0.88^{cd}	28.27 ± 1.12^{c}	25.88 ± 0.68^{b}	16.89 ± 0.58^{a}
Chroma	55.10 ± 0.15^{a}	60.62 ± 2.70^{b}	64.16 ± 1.75^{c}	67.82 ± 0.96^{d}	68.68 ± 1.85^{d}

Values are mean ± standard deviation, n = 3. Values followed by the same letters in the same columns are not significantly different ($p < 0.05$). FM = finger millet. Samples: A = 100% wheat flour (control); B = 90% wheat flour, 10% FM flour; C = 80% wheat flour, 20% FM flour; D = 70% wheat flour, 30% FM flour, E = 60% wheat flour, 40% FM flour.

However, the a* and b* values are always higher in the crust compared to the crumb and this is due to caramelization and Maillard reaction during crust formation. During baking, the two processes are important since they transform reducing sugars to other components and change the color of bread samples (Jusoh et al., 2008). Martins et al. (2000) indicated that caramelization and Maillard browning are governed by baking temperature and time.

3.3 Proximate composition of bread samples

Table 5 shows the proximate composition of bread samples and decreased significantly ($p < 0.05$) with increasing levels of FM flour substitution ranging from 31.20% to 36.08%. Similar initial values for moisture content in bread have been reported (Besbes et al., 2016). The decrease in moisture content of composite bread could be attributed to denaturation of protein which resulted into more interactions between proteins and polysaccharides through electrostatic forces. This led to intermolecular network, water entrapment of water and lower free water content which is associated with decrease of moisture content in foods (Zhang et al., 2016). Moisture is necessary for the keeping quality of bread and high moisture has negative effect on storage stability of bread.

Table 5. Proximate composition of bread samples on dry basis.

Sample	Moisture(%)	Ash(%)	Protein(%)	Crude fiber(%)	Fat(%)	Carbohydrate(%)
A	36.08 ± 0.45^{d}	0.67 ± 0.04^{a}	8.14 ± 0.17^{d}	2.14 ± 0.01^{a}	2.30 ± 0.72^{a}	50.67 ± 0.02^{a}
B	34.72 ± 0.21^{c}	0.91 ± 0.06^{b}	7.77 ±0.05^{c}	2.37 ± 0.03^{b}	2.55 ± 0.05^{b}	51.68 ± 0.24^{b}
C	33.73 ± 1.04^{c}	1.19 ± 0.20^{c}	7.55 ± 0.11^{c}	2.67 ± 0.04^{c}	2.75 ± 0.05^{c}	52.12 ± 0.22^{c}
D	32.70 ± 0.56^{b}	1.25 ± 0.07^{cd}	7.24 ± 0.07^{b}	2.80 ± 0.02^{d}	2.87 ± 0.16^{c}	53.14 ± 0.11^{d}
E	31.20 ± 0.27^{a}	1.39 ± 0.27^{d}	6.75±0.16^{a}	3.02±0.07^{e}	3.17±0.31^{d}	54.47±0.15^{e}

Values are mean ± standard deviation, n = 3. Values followed by the same letters in the same rows are not significantly different ($p < 0.05$). FM = finger millet. Samples: A = 100% wheat flour (control); B = 90% wheat flour, 10% FM flour; C = 80% wheat flour, 20% FM flour; D = 70% wheat flour, 30% FM flour, E = 60% wheat flour, 40% FM flour.

Adeleke & Odedeji (2010) obtained similar results on bread made from wheat and sweet potato flour blends. The ash content increased significantly ($p < 0.05$) with increasing levels of FM flour. The higher ash content in the composite bread indicates higher minerals in FM flour than in the wheat flour since FM grains are a good source of calcium, phosphorus, magnesium, and iron. Our results corroborate with a similar report by Mitiku et al. (2018) for wheat-sweet potato flour composite bread.

Protein content in the bread samples ranged from 6.75% to 8.14%. Bread made from 100% wheat flour (sample A) had significantly ($p < 0.05$) higher protein content than composite bread. The decrease in protein content could be due to low protein content and non-gluten protein of FM flour which might have diluted the protein in wheat flour thereby resulting in low protein level of composite bread (Ijah et al., 2014). The low level of protein in composite bread due to the presence of FM could possibly affect the gluten network and thereby the loaf volume, loaf height as well as the texture of the bread. Therefore, the low level of protein in the present study had negative effect on the textural characteristics of the bread (Menon et al., 2015). The protein content of bread samples in this study is lower than the acceptable range of 10.5% to 14% protein content. Similar findings were reported by Amandikwa et al. (2015) on bread from wheat-yam flour and Mitiku et al. (2018) for wheat-sweet potato flour composite bread. The fat content of the bread increased significantly from 2.30% (Sample A) to 3.17% (Sample F) with increasing levels of FM flour substitution. This could be because FM contains about 1% to 3% fat which could have contributed to the increase in the fat content. Moreover, functionality of fat such as emulsifier capacity will also affect bread texture and bubble formation. The high fat content of the composite flour samples would explain the ability to prepare bread from composite blend without adding any shortening (Menon et al., 2015). Composite bread samples with significantly ($p < 0.05$) higher fat content will be more palatable since fat increases food palatability (Bolarinwa et al., 2019). These results are consistence with Man et al. (2015) on incorporation of chickpea flours to bread. The fiber content increased significantly ($p < 0.05$) with increasing levels of FM flour which ranged from 2.14% to 3.02% for Sample B (10%) and for Sample E (40%) FM flour composite bread. Composite bread had higher fiber content as compared to wheat bread which is an indication that FM flour contains higher fiber content than WF. The crude fiber was above the 1.5% maximum allowable fiber content of bread flour (Oluwamukomi et al., 2011). Carbohydrate contents also increased with increasing levels of FM flour substitution varying from 51.67% (Sample A) to 54.47% (Sample B). The variation in carbohydrate content of control and composite bread could be due to the differences in the contents of other components such as protein, fat and ash. The high level of carbohydrate in composite bread is prudent since starch granules swells and forms a gel when heated in the presence of water and this is important for the characteristic structures and texture of bakery products (Inyang & Asuquo, 2016).

3.4 Physical properties of bread loaves

The volume, weight, and specific volume (Table 6) of the loaves ranged from 256.67 to 400 mL, 141.77 to 148.52 g and 1.81 to 2.69 mL/g, respectively. The loaf volume and specific volume of the bread decreased significantly ($p < 0.05$) with increase in FM flour. Sample A (100% wheat flour) had the highest value of loaf volume and specific volume, 400 mL and 2.69 mL/g, respectively. Sample E had the lowest value of loaf volume (256.67 mL) and specific volume (1.73 mL/g), respectively. The low loaf and specific volumes may be attributed to low levels of gluten in the dough because of the decrease in structure forming proteins in the composite flour which resulted into flour retaining less carbon dioxide gas and a dense texture. Man et al. (2015) demonstrated that the protein content of wheat flour was diluted when partially replaced with banana pseudostem or chickpea flours and interfered with the optimal formation of gluten matrix during mixing of dough, fermentation and baking process. Therefore, dilution of gluten in the flour blends significantly decreased the specific volume of composite bread. In addition, different physicochemical changes in the flour blends which have positive effect on the rheological properties of the dough might subsequently decrease the loaf volume of bread (Sibanda et al., 2015). The ability of the dough not to rise during proofing is due to decrease in structure forming protein which leads to low bread volume (Bibiana et al., 2014). A similar decreasing trend in loaf volume and specific volume was also reported by Amandikwa et al. (2015) for wheat-yam flour composite bread and David Barine (2015) on bread prepared from wheat and unripe plantain composite flours fortified with Bambara groundnut protein concentrate. The loaf weight of composite bread increased significantly ($p < 0.05$) with increasing levels of FM flour incorporation. Sample E had the highest weight value of 148.52 while the lowest value was found on sample A at 141.77 g. This could be due to composite dough retaining less carbon dioxide thereby providing dense bread texture. The increase in loaf weight could be attributed to increased moisture absorption and decreased air entrapment, resulting in heavy dough and heavy loaves (Horsfall et al., 2007).

Table 6. Physical properties of composite bread loaves.

Sample	Volume (mL)	SV (mL/g)	Weight (g)	Crack formation
A	400.00 ± 0.00^{e}	2.69 ± 0.03^{d}	141.77 ± 1.86^{a}	No cracks
B	390.00 ± 10.00^{d}	2.66 ± 0.04^{d}	142.64 ± 0.41^{b}	No cracks
C	348.33 ± 2.89^{c}	2.40 ± 0.05^{c}	145.22 ± 1.45^{cb}	No cracks
D	298.33 ± 2.89^{b}	2.09 ± 0.02^{b}	146.59 ± 1.31^{c}	No cracks
E	256.67 ± 2.89^{a}	1.81 ± 0.08^{a}	148.52 ± 2.10^{d}	No cracks

Values are mean ± standard deviation, n = 3. Values followed by the same letters in the same columns are not significantly different ($p < 0.05$). FM = finger millet. Samples: A = 100% wheat flour (control); B = 90% wheat flour, 10% FM flour; C = 80% wheat flour, 20% FM flour; D = 70% wheat flour, 30% FM flour, E = 60% wheat flour, 40% FM flour. SV = Specific volume.

Moreover, the higher WAC of the composite flour could have contributed to the higher loaf weight when compared to 100% wheat bread (Okorie & Onyeneke, 2012). Similar results were reported for bread from wheat flour supplemented with non-wheat flours (David Barine, 2015). The composite bread did not show any crack formation and similar results were reported by Ukpabia & Uchechukwu (2001) on 100% Chinese yam bread.

4 Conclusions

Water absorption capacity and oil absorption capacity of the flours increased with increasing finger millet flour contents while emulsion activities decreased simultaneously. Incorporation of finger millet flour resulted in bread with low loaf volume and specific volume but the weight of the bread was increased. The results obtained showed that wheat flour combined with finger millet flour increased the fiber, carbohydrates, and ash content. However, considering both the physical characteristics and decrease in protein content of the breads, the inclusion of finger millet flour should not exceed 10%.

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