EFFECT OF *BRACHYSTEGLIA EURYCOMA* FLOUR ADDITION ON THE PHYSICOCHEMICAL PROPERTIES OF WHOLE MILLET FLOUR AND THE SENSORY ATTRIBUTES OF ITS GLUTEN-FREE BREAD

– Research paper –

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Abstract: This study evaluated the effect of addition of *Brachystegia eurycoma* flour (BEF), a natural source of hydrocolloids, on the physicochemical properties of whole millet flour (WMF) and the sensory attributes of its gluten-free bread. BEF and sodium carboxymethyl cellulose (a reference hydrocolloid) were added to WMF at 1.5 and 3% proportions, and breads were baked from the blends. Wheat flour (100% CWF) bread served as the control. Amylose level decreased significantly ($p < 0.05$), while water absorption capacity, peak and final viscosities of the blends increased with increasing proportion of BEF. The 100% CWF bread had better sensory qualities than WMF-BEF breads. Hence, BEF improved the physicochemical properties of WMF-BEF blend, but did not alter the sensory qualities of its gluten-free bread.

Keywords: Whole millet flour; *Brachystegia eurycoma*; Gluten-free bread; Celiac disease; Sensory qualities

INTRODUCTION

Baked food products from wheat pose problem for many celiac disease patients, due to the presence of gluten in them. Research has shown that adhering strictly to diets that do not contain gluten (gluten-free diets) throughout the celiac disease patients' lifetime is the only efficacious remedy for such condition (Anton and Artfield, 2008). However, the absence of gluten poses a major challenge to bakers. Consequently, a large number of gluten-free food products sold in the market have low qualities such as unappealing flavor and poor mouth feel (Arendt et al., 2002). To produce gluten-free products, different flours and starches, and some other substances such as hydrocolloids, proteins and enzymes that mimic the visco-elastic attributes of gluten have been applied (Anton and Artfield, 2008).

Hydrocolloids (also known as gums) are extensively utilized in the food industry as a class of additives. They modulate the texture as well as the rheology of aqueous systems by stabilizing suspensions, emulsions and foams (Anton and Artfield, 2008). They comprise a group of polysaccharides that is soluble in water, and has

different chemical structures that impart some functional characteristics, which make them appropriate for various uses in the food industry (Rosell et al., 2007).

In addition to their application as gluten replacements in gluten-free products, hydrocolloids are added in foods to enhance texture, increase the retention of moisture, slow down the retrogradation of starch, and to extend the product's overall quality during storage (Anton and Artfield, 2008). However, the use of synthetic hydrocolloids and other additives to enhance the baked products' quality may result in an increased cost of their production (Ohimain, 2014). The use of natural hydrocolloids, which are readily available, may be a better substitute for the synthetic hydrocolloids, thereby reducing the cost of production. Plant materials are known to be the main sources of natural hydrocolloids. In this context, one of the commonly known plant sources of natural hydrocolloids is *Brachystegia eurycoma* (Nwakaudu et al., 2017).

Brachystegia eurycoma Harm, family *Caesalpinioideae*, is a woody plant that grows in the forest regions of Cameroun and southern Nigeria. It is a lesser-known leguminous plant. Due to its high hydrocolloids level (Nwakaudu et

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al., 2017), the flour of its edible seeds serves as a thickener in the preparation of traditional soups in West Africa (Uhegbu et al., 2009). It is also used for the production of starch and for making baked products (Ikegwu et al., 2010). In addition to its hydrocolloids content, *B. eurycoma* flour is also a rich natural source of phenolic compounds that possesses antidiabetic activity (Ironi et al., 2015a; Ironi et al., 2015b).

Millet is a small-seeded grass, grown in many parts of the world as cereal food. It thrives on dry and low fertility soils, especially in hot climate regions, with short rainfall periods (Kwaw and Augustina, 2013). Millet grain has a good nutritive quality, as it contains 1.5-5% fat, 2-4% minerals, 6-19% protein, 60-70% dietary carbohydrates, 12-20% dietary fiber, and many phytochemicals (Hadimani et al., 1995). Millets are suitable for celiac disease

patients, as they do not contain gluten (Annor et al., 2017). In addition, millets and millet-based products have been reported to possess hypoglycemic property, making them suitable for the management of type II diabetes (Shukla and Srivastava, 2014; Ren et al., 2016).

The impact of additives on the quality of gluten-free bread has been the focus of many previous studies. However, a careful search of the existing literature revealed a paucity of scientific information on the influence of natural sources of hydrocolloids on the properties of whole millet gluten-free flour and its bread. Hence, the effect of *Brachystegia eurycoma* flour (a natural source of hydrocolloids) addition on the physicochemical properties of whole millet flour and the sensory attributes of its gluten-free bread is evaluated in this study.

MATERIALS AND METHODS

Materials

The materials used in this research were commercial wheat (*Triticum aestivum*) flour, whole millet (*Pennisetum glaucum*) grains, *Brachystegia eurycoma* (a natural source of hydrocolloids (Figure 1), and synthetic hydrocolloid (sodium carboxymethyl cellulose). The materials were procured from a market in Ilorin, Kwara State. All the chemicals and reagents used for the experiments were of analytical grades.

Preparation of samples and flour blends

The samples – whole millet grains and *Brachystegia eurycoma* seeds were milled separately to obtain their individual flours. Each was then packed in a sealed transparent polythene bags, and then kept in air-tight containers, which were properly labeled and stored at room temperature prior to analysis. Gluten-free flour blends were formulated by incorporating one of *Brachystegia eurycoma* flour (BEF) and sodium carboxymethyl cellulose (SCMC) to whole millet

flour (WMF) at 1.5% and 3% proportions, to obtain 98.5%WMF-1.5%BEF, 97%WMF-3%BEF, 98.5%WMF-1.5%SCMC and 97%WMF-3%SCMC blends. Commercial wheat flour (CWF) served as the control flour.

Determination of gluten content

The method of Usurp et al. (1982) was followed to quantify the gluten level of the flour samples. A portion (20 g) of flour sample and distilled water (10 mL) were mixed in a centrifuge tube, and the suspension was left for 15 min. Next, the suspension was stirred using the stirrer. The flour mixture was rolled into a ball and it was dipped into a beaker containing clean water. This was left to stand for 30 min, after which it was washed under running water, ensuring that no part was lost. The elastic gluten obtained after washing was cut into bit, arranged into a pan, and then kept in the oven overnight to get the dried gluten. It was weighed, and percentage gluten content was calculated as follow:

$$\% \text{ gluten content} = \frac{\text{Weight of dried gluten (g)} \times 100}{\text{Weight of flour (g)}}$$

Commercial wheat flour

Pearl millets

Brachystegia eurycoma seeds

Figure 1. Plant materials

Determination of amylose and amylopectin concentrations

Amylose content of flour samples was determined using the method of Juliano et al. (1981). A portion (100 mg) of sample, 1 mL of ethanol (100%, v/v) and 9.2 mL of sodium hydroxide (1 M) were mixed in a 50 mL centrifuge tube, and the centrifuge tube was covered. The starch in the sample was gelatinized by heating the mixture for 10 min in a boiling water bath to, after which it was taken out of the water bath and cooled to room temperature. Next, it was made up to the mark with distilled water, shaken properly, and 5 mL of the mixture was pipette into a 50 mL volumetric flask. One mL of acetic acid and iodine solution (2 mL) were added, and the reaction mixture was made up to mark with distilled water. Absorbance was read using spectrophotometer at 620 nm against reagent blank. Subsequently, amylose concentration of the flour samples was computed using a standard amylose.

Percentage amylopectin concentration of the samples was estimated by difference, based on the formula previously reported by Juan et al. (2006) as follows:

$$\% \text{ Amylopectin} = 100 - \% \text{ amylose.}$$

Determination of functional properties (swelling power, water absorption capacity and bulk density)

The methods reported by Nwakaudu et al. (2017) were followed to quantify the swelling power, water absorption capacity and bulk density of the flour samples.

Determination of pasting properties

The determination of the pasting properties of the flour samples was carried using a Rapid Visco Analyzer (model: RVA-4, Perten Scientific, Springfield, IL) as described by Deffenbaugh and Walker (1989). The machine (RVA) was connected to a personal computer with Thermocline software. A suspension of the sample (3 g of flour in 25 mL of distilled water) was prepared in an aluminum canister and loaded in the RVA. The analysis was carried out under constant stirring (160 RPM) using the following programme: a holding period of 5 min at 25°C; a heating rate of 5°C/min between 25 and 95°C; a holding period of 5 min at 95°C; a cooling rate of 5°C/min to 25°C; and a holding period of 5 min at 25°C. The pasting properties (peak, trough,

breakdown, final, set-back viscosities, peak time, pasting temperature) were read on the personal computer. Viscosity profiles were expressed in Rapid Visco Analyzer units (RVU); while peak time and pasting temperature were expressed in minutes and °C, respectively.

Preparation of gluten-free bread

The bread formulation was according to Siller (2006) with slight modification. The dough formulation consisted of flours, sugar, salt, yeast, shortening and water, as indicated in Table 1. The ingredients were mixed and kneaded manually to obtain uniform dough. Thereafter, the dough was weighed and placed in a baking pan that had been smeared with shortening, and baked at 330°C for 10 min. After baking, the bread loaf was placed in a cooling rack until it cooled to room temperature. CWF bread served as control bread.

Sensory evaluation of bread samples

Freshly baked gluten-free breads of 100%WMF, the blends (98.5%WMF-1.5%BEF, 97%WMF-3%BEF, 98.5%WMF-1.5%SCMC and 97%WMF-3%SCMC) and a control bread of 100%CWF were used for sensory evaluation, which was conducted by adopting the method described by Ranasalva and Visvanathan (2014) with modification. Ethical approval (MOH/KS/EU/777/410) was obtained from Kwara State Ministry of Health, Ilorin. The attributes that were evaluated for include: colour, flavour, taste, chewiness and overall acceptability of the bread samples. Twenty-five panelists (males and females) of age ranging from 18 – 25 years, who represented students of Kwara State University, Malete, evaluated the bread samples using a hedonic questionnaire on a nine-point scale. On the nine-point scale, '1' represented extremely dislike; '2' represented dislike very much; '3' represented dislike moderately; '4' represented dislike slightly; '5' represented neither like nor dislike; '6' represented like slightly; '7' represented like moderately; '8' represented like very much; and '9' represented like extremely.

Data analysis

Results of triplicate experiments, expressed as mean $\pm$ standard deviation (SD) were subjected to ANOVA (One-way analysis of variance) using SPSS 21 software. Also, mean values were compared using Duncan's multiple range test at 95% confidence level.

Table 1. Dough formula

Dough	Ingredients (g)								
	CWF	WMF	BEF	SCMC	Sugar	Salt	Shortening	Active dry yeast	Water
100%CWF	100	–	–	–	3.0	1.5	6.0	0.8	60
100%WMF	–	100	–	–	3.0	1.5	6.0	0.8	60
98.5%WMF-1.5%BEF	–	98.5	1.5	–	3.0	1.5	6.0	0.8	60
97%WMF-3%BEF	–	97	3	–	3.0	1.5	6.0	0.8	60
98.5%WMF-1.5%SCMC	–	98.5	–	1.5	3.0	1.5	6.0	0.8	60
97%WMF-3%SCMC	–	97	–	3	3.0	1.5	6.0	0.8	60

CWF, commercial wheat flour; WMF, whole millet flour; BEF, *Brachystegia eurycoma* flour; SCMC, sodium carboxymethyl cellulose

RESULTS AND DISCUSSIONS

Gluten, amylose and amylopectin contents of the flour samples

The gluten, amylose and amylopectin concentrations of the flour samples are presented in Table 2. Commercial wheat flour (100%CWF) had gluten content of $14.53 \pm 0.35\%$, which is higher than the value (11.35%) in wheat flour (Maida) reported by Rodge et al. (2012). Expectedly, no gluten was detected in the whole millet and *B. eurycoma* flour (100%WMF and 100%BEF) samples. Omary et al. (2012) had earlier reported on millet as a gluten-free cereal. Legumes, of which *B. eurycoma* is an example, have been suggested as an alternative to common flours for the preparation of gluten-free food products, due to the functional attributes of their proteins (Miñarro et al., 2012).

The amylose, amylopectin contents and the amylose/amylopectin ratio of the individual flours (100%CWF, 100%WMF and 100%BEF) varied significantly ($p < 0.05$). WMF (100%) had the highest levels of amylose and amylose/amylopectin ratio ($28.62 \pm 0.14\%$ and

0.40 ± 0.00 , respectively) and the least level of amylopectin ($71.38 \pm 0.14\%$), while 100%BEF had the least level of amylose and amylose/amylopectin ratio ($1.35 \pm 0.21\%$ and 0.01 ± 0.00 , respectively) and highest level of amylopectin ($98.65 \pm 0.21\%$). Expectedly, SCMC, a reference hydrocolloid, had a lower level of amylose ($0.10 \pm 0.14\%$) and a higher level of amylopectin ($99.90 \pm 0.14\%$) than the flours. The amylose and amylopectin concentrations of the 100%BEF were different from the values ($0.82 \pm 0.03\%$ and $99.18 \pm 0.94\%$, respectively) reported by Irondi et al. (2019). However, the amylose and amylopectin contents of the 100%CWF (24.48 ± 0.35 and $75.52 \pm 0.35\%$, respectively) are consonant with the values reported by Irondi et al. (2017) for 100% wheat flour (24.50 ± 0.23 and $75.50 \pm 0.23\%$, respectively). Consistently, the amylopectin contents of the flour samples tested in this present study were higher than their corresponding amylose contents, corroborating previous research findings that amylopectin is the predominant component of most starches (Yotsawimonwat et al., 2008).

Table 2. Gluten, amylose and amylopectin contents of flour samples

Samples	Gluten content (%)	Amylose (%)	Amylopectin (%)	Amylose/Amylopectin
100%CWF	14.53 ± 0.35	24.48 ± 0.35^c	75.52 ± 0.35^f	0.32 ± 0.01^b
100%WMF	ND	28.62 ± 0.14^h	71.38 ± 0.14^a	0.40 ± 0.00^e
100%BEF	ND	1.35 ± 0.21^b	98.65 ± 0.21^g	0.01 ± 0.00^a
100%SCMC	ND	0.10 ± 0.14^a	99.90 ± 0.14^h	0.00 ± 0.00^a
98.5%WMF-1.5%BEF	ND	27.47 ± 0.92^{ef}	72.53 ± 0.92^{bc}	0.38 ± 0.02^d
97%WMF-3%BEF	ND	26.72 ± 0.42^{de}	73.28 ± 0.42^{cd}	0.37 ± 0.01^{cd}
98.5%WMF-1.5%SCMC	ND	27.77 ± 0.21^{fg}	72.23 ± 0.21^{ab}	0.39 ± 0.00^{de}
97%WMF-3%SCMC	ND	26.27 ± 0.63^d	73.73 ± 0.63^d	0.36 ± 0.01^c

Data are the mean values $\pm$ SD of triplicate determinations. Data having different lowercase superscript letters along the same column differ significantly ($p < 0.05$). CWF, commercial wheat flour; WMF, whole millet flour; BEF, *Brachystegia eurycoma* flour; SCMC, sodium carboxymethyl cellulose; ND, not detected

The addition of each of BEF and SCMC resulted in a significant decrease ($p < 0.05$) in the amylose content of the WMF-BEF and WMF-SCMC blends, and a concomitant decrease in their amylose/amylopectin ratios. This trend is similar to the finding of Ironi et al. (2019) for high quality cassava flour substituted with *B. eurycoma* flour seed. This notwithstanding, the amylose contents of 98.5%WMF-1.5%BEF and 98.5%WMF-1.5%SCMC, as well as those of 97%WMF-3%BEF and 97%WMF-3%SCMC were comparable ($p > 0.05$).

The amylose and amylopectin contents of flours are known to have impact on their functional properties, as well as on their applications in food and industrial products (Ironi et al., 2017). Also, the ratio of amylose to amylopectin concentrations of flours has influence on their glycaemic index, such that a lower amylose and a higher amylopectin concentrations result in a higher glycaemic index (Shanita et al., 2011). This is attributed to the relative ease of digestion of amylose and amylopectin by the α -amylase present in the duodenum of humans as reported by Birt et al. (2013). Thus, relative to 100%CWF, the 100%WMF with a higher amylose contents ($28.62 \pm 0.14\%$) and amylose/amylopectin ratio (0.40 ± 0.00) may have a lower digestibility and a concomitant lower glycaemic index (Riley et al., 2006).

Functional properties of flour samples

Table 3 presents the functional properties (swelling power, water absorption capacity and bulk density) of the flour samples. The swelling power, water absorption capacity and bulk density of the individual flours varied significant ($p < 0.05$); with 100%BEF having the highest swelling power (12.30 ± 0.42 g/g) and bulk density (0.8 ± 0.01), and 100%CWF having the highest water absorption capacity ($348.5 \pm 2.12\%$). However, the swelling power (19.58 ± 0.38 g/g) and water absorption capacity ($455.22 \pm 1.73\%$) of SCMC were significantly higher than those of all the flours. The variations observed in the water absorption capacity of the flour samples may be attributed to differences in their protein concentrations, structure, degree of interaction with water and their conformational characteristic, and the presence of different hydrophilic carbohydrates in the flours (Butt and Batool, 2010; Kaur et al., 2017).

The bulk density of 100%BEF was within the range of 0.116 to 1.44 g/mL reported by Nwosu et al. (2011), as the bulk density of *B. eurycoma* stored in different conditions. Similarly, the bulk

density of 100%CWF (0.69 ± 0.01 g/mL) agree with the 0.66 ± 0.03 g/mL reported for wheat flour by Lesetja et al. (2019). Also, the water absorption capacity of 100%BEF ($223.61 \pm 3.68\%$, equivalent to 2.23 g/g) was within the range of 0.70 - 2.70 g/g reported by Nwosu et al. (2011). However, the water absorption capacity of the 100%CWF ($348.5 \pm 2.12\%$) was higher than the 140 - 142% water absorption capacity range for 100% wheat flour reported by Suresh et al. (2015). The swelling power of 100%CWF (8.91 ± 0.22 g/g) was lower than the 17.91 ± 1.34 g/mL reported by Lesetja et al. (2019), while the swelling power of 100%BEF (12.30 ± 0.42 g/g) was much higher than the range (1.25 - 2.70 g/g) reported by Nwakaudu et al. (2017).

There was no significant variation ($p > 0.05$) in the swelling power of the 100%WMF and those of the 98.5%WMF-1.5%BEF, 97%WMF-3%BEF and 98.5%WMF-1.5%SCMC blends. However, the swelling power of the 97%WMF-3%SCMC blend was significantly lower ($p < 0.05$) than that of the 100%WMF. Furthermore, there was a consistent significant increase ($p < 0.05$) in the water absorption capacity of all the WMF-BEF and WMF-SCMC blends, relative to the 100%WMF; albeit, the increase was comparable ($p > 0.05$) among the blends. The increased water absorption capacity observed for WMF-BEF and WMF-SCMC blends with increasing proportions of each of BEF and SCMC addition is in agreement with the report of Rodge et al. (2012) that guar gum incorporation in wheat flour increased the water absorption capacity of dough, as the concentration of guar increased. This increase in the water absorption capacity of the blends may ensure product cohesiveness, as earlier suggested by Ogunlakin et al. (2012).

Furthermore, relative to the 100%WMF, the addition of BEF led to a significant increase ($p < 0.05$) in the bulk density of the WMF-BEF blends, whereas the addition of SCMC had no significant effect ($p > 0.05$) on the bulk density of WMF-SCMC blends. Bulk density was reported by Iwe and Onalope (2001) and Akubor (2007) to be an indication of product porosity and a function of flour wettability. Thus, while high bulk density is desirable for greater ease of dispensability and paste thickness reduction (Udensi and Eke, 2000); a low bulk density is a desirable physical quality, when considering storability and transportation, since the products could be transported and distributed easily (Agunbiade and Sanni, 2001).

Pasting properties of flour samples

Pasting properties, as described by Alcázar-Alay and Meireles (2015), represent changes in starch following gelatinization in excess volume of water, after a definite cycle of heating and cooling under shear forces. Table 4 presents the pasting properties (peak viscosity, trough, breakdown, final and set-back viscosities, peak time and pasting temperature) of the flour samples. The peak, trough, breakdown, final and set-back viscosities differed significantly ($p < 0.05$) among the individual flours. Interestingly, 100%BEF had the highest peak (1465.08 ± 3.37 RVU), trough (697.92 ± 2.69 RVU), breakdown (767.17 ± 3.68 RVU), final (1418.00 ± 3.52 RVU) and setback (720.08 ± 4.03 RVU) viscosities, relative to 100%CWF, 100%WMF and SCMC. Furthermore, a comparison of the pasting properties of 100%CWF and 100%WMF reveals that

100%CWF had higher peak, trough, breakdown, final and set-back viscosities, as well as a higher pasting temperature than 100%WMF. However, the addition of 1.5 and 3% of each of BEF and SCMC led to a significant increase ($p < 0.05$) in the peak, trough and final viscosities of the WMF-BEF and WMF-SCMC blends, relative to the 100%WMF. There was also a significant decrease in the pasting temperature of the WMF-BEF and WMF-SCMC blends due to the addition of 3%BEF, 1.5 and 3%SCMC, when compared to the 100%WMF.

The high pasting properties of the 100%BEF obtained in this study may partly be the basis for its use in different food products. The increase in the peak, trough and final viscosities of the WMF-BEF blends, relative to the 100%WMF further confirms BEF as a rich natural source of hydrocolloids.

Table 3. Functional properties of the flour samples and their blends

Sample	Swelling power (g/g)	Water absorption capacity (%)	Bulk density (g/mL)
100%CWF	8.91 ± 0.22^d	348.5 ± 2.12^d	0.69 ± 0.01^{bc}
100%WMF	8.17 ± 0.01^{bc}	105.37 ± 0.72^a	0.63 ± 0.01^a
100%BEF	12.30 ± 0.42^e	223.61 ± 3.68^c	0.8 ± 0.01^d
100%SCMC	19.58 ± 0.38^f	455.22 ± 1.73^e	0.68 ± 0.01^b
98.5%WMF-1.5%BEF	8.59 ± 0.04^{cd}	119.04 ± 2.20^b	0.70 ± 0.01^c
97%WMF-3%BEF	8.72 ± 0.03^{cd}	119.90 ± 1.27^b	0.68 ± 0.01^b
98.5%WMF-1.5%SCMC	7.62 ± 0.03^{ab}	119.90 ± 0.14^b	0.64 ± 0.00^a
97%WMF-3%SCMC	7.39 ± 0.07^a	115.92 ± 0.11^b	0.63 ± 0.01^a

Data are the mean values $\pm$ SD of triplicate determinations. Data having different lowercase superscript letters along the same column differ significantly ($p < 0.05$). CWF, commercial wheat flour; WMF, whole millet flour; BEF, *Brachystegia eurycoma* flour; SCMC, sodium carboxymethyl cellulose

Table 4. Pasting properties of the flour samples and their blends

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Set-back viscosity (RVU)	Peak time (min)	Pasting temp. (°C)
100%CWF	203.92 ± 2.70^e	127.21 ± 0.96^d	76.71 ± 4.02^d	289.84 ± 3.34^e	162.63 ± 3.42^f	6.24 ± 0.85^b	91.30 ± 2.38^e
100%WMF	106.17 ± 1.49^a	70.67 ± 0.81^a	35.50 ± 3.72^b	172.83 ± 1.57^a	102.17 ± 3.22^c	5.53 ± 0.11^{ab}	79.95 ± 1.88^d
100%BEF	1465.08 ± 3.37^g	697.92 ± 2.69^g	767.17 ± 3.68^f	1418.00 ± 3.52^g	720.08 ± 4.03^g	5.80 ± 0.13^{ab}	76.55 ± 1.99^d
100%SCMC	900.63 ± 1.32^f	608.09 ± 2.15^f	292.54 ± 4.20^e	732.54 ± 2.84^f	124.46 ± 3.08^e	5.44 ± 0.44^{ab}	50.28 ± 0.51^a
98.5%WMF-1.5%BEF	138.00 ± 2.49^b	105.79 ± 4.02^b	32.21 ± 2.93^b	223.63 ± 1.63^c	117.84 ± 3.13^d	5.54 ± 0.63^{ab}	79.90 ± 1.27^d
97%WMF-3%BEF	179.84 ± 2.31^d	117.21 ± 1.58^c	30.25 ± 2.46^b	211.42 ± 3.58^b	94.21 ± 1.50^b	4.80 ± 0.99^a	65.85 ± 1.10^c
98.5%WMF-1.5%SCMC	208.33 ± 1.15^e	149.58 ± 2.15^e	58.75 ± 0.86^c	261.00 ± 0.31^d	111.42 ± 1.43^d	5.57 ± 0.38^{ab}	62.20 ± 1.08^b
97%WMF-3%SCMC	156.84 ± 1.58^c	147.92 ± 0.27^e	8.92 ± 0.17^a	227.21 ± 2.02^c	79.29 ± 1.58^a	6.40 ± 0.28^b	59.85 ± 1.41^b

Data are the mean values $\pm$ SD of triplicate determinations. Data having different lowercase superscript letters along the same column differ significantly ($p < 0.05$). CWF, commercial wheat flour; WMF, whole millet flour; BEF, *Brachystegia eurycoma* flour; SCMC, sodium carboxymethyl cellulose

SCMC, a reference hydrocolloid, also had a similar effect on the peak, trough and final viscosities of the WMF-SCMC blends. It had earlier been established that hydrocolloids addition increases the viscosity of starch and affects the gelatinization and retrogradation attributes of starch, usually via the strong interactions of amylose with gum (Kowalski et al., 2008; Chandanasree et al., 2016). A recent study reported that substitution with *B. eurycoma* seed flour improved the pasting properties of high quality cassava flour (Ironi et al., 2019). Other previous studies also affirmed that the composite viscosity resulting from the embedding of starch in a solution of hydrocolloid, would be influenced by alterations in the two phases and their interactions with each other (Sullo and Foster, 2010; Díaz-Calderon et al., 2018). Peak viscosity is indicative of the water binding capacity of a particular flour sample (Abiodun and Akinoso, 2014), reflecting the tendency of the granules of starch to swell freely before their physical breakdown (Wireko-Manu et al., 2011). In agreement with the report of Zaidul et al. (2007), the lower amylose contents of BEF and SCMC may have led to the higher peak viscosity of the WMF-BEF and WMF-SCMC blends. Among the pasting parameters, final viscosity is the most commonly used parameter for ascertaining the quality of a given flour or starch sample (Maziya-Dixon et al., 2005). It indicates the stability of the cooked starch and the resistance of its paste to shear force during stirring. Thus, the higher final viscosity of the WMF-BEF and WMF-SCMC blends suggests that they may have a better quality than the 100% WMF. Consequently, the blends may be more suitable than the 100% WMF for obtaining food products that require starch of high viscosity (Moorthy, 2002; Ironi et al., 2019). The concomitant decrease in the pasting temperature of the WMF-BEF (3%BEF) and WMF-SCMC blends (1.5 and 3% SCMC) with the

increase in their peak and final viscosities gives further credence to the improvement of the pasting properties of the blends. Offia-Olua (2014) reported that pasting temperature (that is, the least temperature needed to cook a given starchy sample) attainment is important for adequate swelling, gelatinization, as well as pasting of starch during processing. Hence, the lower pasting temperature of the blends indicates that cooking the blends may cost lesser energy than the 100% WMF.

Sensory attributes of the bread samples

The sensory attributes (colour, flavour, taste, chewiness and overall acceptability) are presented in Table 5. Relative to the 100% CWF bread (reference bread), the breads of 100% WMF and the blends (98.5% WMF-1.5% BEF, 97% WMF-3% BEF, 98.5% WMF-1.5% SCMC and 97% WMF-3% SCMC) were rated significantly lower ($p < 0.05$) in all the sensory attributes. However, relative to the 100% WMF bread, there was a marginal improvement in the following: the colour of the WMF-SCMC breads; the flavour of the 98.5% WMF-1.5% BEF, 97% WMF-3% BEF and 98.5% WMF-1.5% SCMC breads; the taste of the 98.5% WMF-1.5% BEF, 97% WMF-3% BEF, 98.5% WMF-1.5% SCMC and 97% WMF-3% SCMC breads; and the overall acceptability of the 98.5% WMF-1.5% SCMC bread.

The lower sensory ratings, especially the taste, flavor and overall acceptability of the breads of 100% WMF and the blends may be attributed to the bitter taste of millet (Matthew et al., 2016), which had the highest proportion (98.5% or 97%) in the flours blends than each of the BEF and SCMC (1.5 and 3%). Tortoe et al. (2019) also reported that increasing the proportion of millet in millet-wheat composite flour resulted in lower attributes and acceptability scores.

Table 5. Sensory attributes of bread samples

Bread	Colour	Flavour	Taste	Chewiness	Odour	Overall acceptability
100% CWF	7.17±1.85 ^b	5.75±1.60 ^b	6.17±1.80 ^b	6.67±2.10 ^b	6.67±1.88 ^b	6.58±2.23 ^b
100% WMF	3.42±1.98 ^a	3.25±1.96 ^a	2.67±1.92 ^a	4.17±1.85 ^a	4.17±1.47 ^a	3.25±2.53 ^a
98.5% WMF-1.5% BEF	3.42±1.88 ^a	3.75±1.82 ^a	3.25±1.70 ^a	3.42±2.02 ^a	4.25±1.71 ^a	2.83±1.59 ^a
97% WMF-3% BEF	2.92±1.93 ^a	3.50±2.02 ^a	3.25±2.09 ^a	3.17±1.47 ^a	3.92±2.23 ^a	2.67±1.88 ^a
98.5% WMF-1.5% SCMC	4.08±2.15 ^a	4.08±1.78 ^a	3.08±1.56 ^a	3.67±1.44 ^a	3.75±1.55 ^a	3.42±1.44 ^a
97% WMF-3% SCMC	3.58±1.83 ^a	3.25±1.66 ^a	3.25±2.01 ^a	3.17±1.59 ^a	3.42±1.31 ^a	3.25±2.05 ^a

Data are the mean values ± SD of replicate evaluations. Data having different lowercase superscript letters along the same column differ significantly ($p < 0.05$). CWF, commercial wheat flour bread; WMF, whole millet flour bread; BEF, *Brachystegia eurycoma* flour; SCMC, sodium carboxymethyl cellulose

CONCLUSIONS

The addition of 1.5 and 3% *B. eurycoma* flour (BEF) to whole millet flour (WMF) led to a decrease in the amylose level of 98.5%WMF-1.5%BEF and 97%WMF-3%BEF blends, while the water absorption capacity, peak and final viscosities of the blends increased. The sensory qualities of the gluten-free 98.5%WMF-1.5%BEF and 97%WMF-3%BEF breads were lower than those of commercial wheat flour (100%CWF) bread, but were comparable to those of 100%WMF, 98.5%WMF-1.5%SCMC and

97%WMF-3%SCMC breads. Hence, the addition of BEF improved the physicochemical properties of WMF, but did not alter the sensory qualities of its gluten-free bread. BEF may be a viable natural substitute for the synthetic hydrocolloids, sodium carboxymethyl cellulose, in developing WMF-based gluten-free bread for people susceptible to gluten allergy and the resultant celiac disease. However, the formula of the WMF-BEF gluten-free bread needs to be improved on, in order to enhance its sensory attributes relative to those of 100%CWF bread.

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