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PHYSICOCHEMICAL AND SENSORY QUALITIES OF GLUTEN-FREE COOKIES MADE FROM BIOFORTIFIED YELLOW MAIZE FLOUR SUPPLEMENTED WITH *BRACHYSTEGIA EURYCOMA* FLOUR

– Research paper –

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Abstract: Recent research has focused on enhancing the overall quality of gluten-free products. This study evaluated the physicochemical properties of biofortified yellow maize flour (BMF) supplemented with *Brachystegia eurycoma* flour (BEF) at varied amount (2.5, 5, 7.5 and 10 %), and sensory qualities of their gluten-free cookies. Sodium carboxyl methylcellulose (SCMC) served as reference hydrocolloid while refined wheat flour cookies served as reference cookies. The addition of BEF significantly ($p < 0.05$) decreases the functional properties (bulk density, water absorption capacity, soluble sugar and amylose content) of BMF. BMF blends has higher ($p < 0.05$) pasting properties than the 100% BMF except the pasting temperature. Among all the flour samples, 100% BMF has the highest level of crude protein (12.78±0.08 %) and fiber (2.94 ± 0.12 %) but the lowest total carbohydrate (74.76 ± 0.14 %). The cookies made from 100% RWF have the lowest value for appearance (7.2 ± 1.02) and color (7.2 ± 0.75) and 2.5%BEF-97.5% BMF cookies have the highest over acceptability value (8.40 ± 1.20). Hence, the physicochemical properties of BMF as well as their cookies sensory qualities can be enhanced by supplementing with BEF.

Keywords: Gluten-Free Cookies, *Brachystegia eurycoma*, Sensory qualities, Biofortified Yellow Maize, Gluten

INTRODUCTION

Cookies are one of the extensively consumed snack by human beings (Abdulrazaaq et al., 2024). They are produced in different flavor and shape, and they have considerable price, quality, nutritional value and shelf life (Elif and Duygu, 2020; Mehrdad et al., 2022). Cookies are commonly baked from refined wheat flours because they compose of gluten that render superior viscoelastic properties to their dough over gluten-free cereals (Elif and Duygu, 2020; Irondi et al., 2023; Abdulrazaaq et al., 2024). However, this gluten is problematic for consumers affected BMF gluten-associated disorders like celiac disease, non-celiac gluten sensitivity, gluten ataxia, wheat allergies, and exercise induced anaphylaxis (Khairuddin and Lasekan 2021; Imam et al., 2024). The only efficacious treatment for these disorders is total abstinence from gluten-containing diets (Lamacchia et al., 2014; Irondi et al., 2021). This brought about the idea of developing gluten free (GF) products like GF cookies, bread and cake among others.

In recent time, GF products have also been embraced due to other non-communicable diseases related to nutrition, rising price of wheat flour and consumers' demands for healthy diets (Irondi et al., 2023; Imam et al., 2024). However, different flours, ingredients or additives which has similar visco-elastic properties like gluten are required to produce high-quality GF-baked products (Mir et al., 2016). In the production of GF cookies, sorghum, tambourine, millet, soy and buckwheat flours have been used (Demirceken, 2011). Although, the flour and starch of rice and corn (maize) are the most used (Elif and G. Duygu, 2020).

After rice and wheat, maize (Zea mays L.) is the third most significant cereal crop cultivated worldwide (Yousaf et al., 2020). It is an annual crop primarily grown for its grain which serve as feed for both animal and human thereby providing them with important nutrients such as protein, carbohydrate, minerals (e.g. iron), and vitamin B (Siwela et al., 2020; Abdulrazaaq et al., 2024).

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However, it is deficient in some micronutrients such as low vitamin A levels due to the absent of pro vitamin A carotenoids (Zuma et al., 2022). Bio fortification is one of the strategies used in addressing this challenge. Bio fortified maize has an enhanced vitamin A and improved carotenoids contents. More so, it is more tolerant to drought and disease than the native (white and yellow) maize (Awobusuyi et al., 2016; Zuma et al., 2022). Although the white maize is the most consumed maize varieties (Ekpa et al., 2018), interest in the bio fortified yellow maize is increasing due to its potential food applications and health benefits attributed to its and physicochemical and bioactive constituents (Elemosho et al., 2020).

Brachystegia eurycoma (BE) is an underutilized legume which has been recommended as a natural hydrocolloid source (Nwakaudu et al., 2017). It is also an important source of carbohydrate, calories, protein, certain minerals and vitamins (Nwosu 2012; Abdulrazaaq et al., 2024) and are rich in some phytochemicals with potential nutraceutical importance (Irondi et al., 2015a; Irondi et al., 2015b; Irondi et al., 2022; Abdulrazaaq et al., 2024). Its potential to replace gluten in GF bread based on whole millet flour was recently reported by Irondi et al. (2021, 2022). However, there is a scarcity of scientific information from exiting literature on the use of BE for GF cookies and as a blend of biofortified maize. Hence, the physicochemical and sensory qualities of GF cookies baked from biofortified yellow maize flour supplemented with *Brachystegia eurycoma* are evaluated in this study.

MATERIALS AND METHODS

B. eurycoma (BE) seed, biofortified yellow maize grains (Figure 1), white maize grain, sodium carboxyl methylcellulose (SCMC) (synthetic hydrocolloids) and refined wheat flour *(Triticum aestivum*) (RWF) were used in this study. They were procured from a local market in Ilorin, Kwara State. Analytically graded chemicals and reagents were also used in the study.

Samples preparation

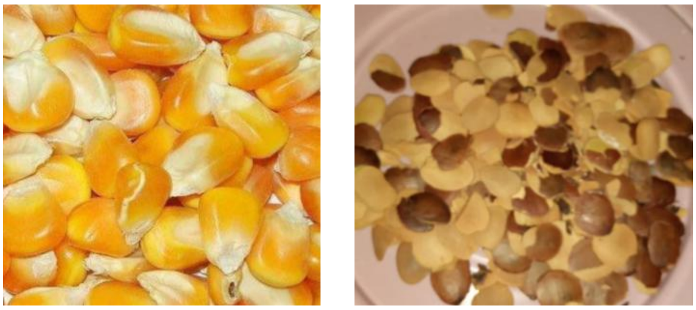
Biofortified yellow maize grains, white maize grain and BE seeds were milled their individual flours respectively. BE flour (BEF) and SCMC (reference hydrocolloid) were incorporated to biofortified yellow millet flour (BMF) at four varied ratio (2.5, 5, 7.5 and 10%) respectively. White maize and RWF served as control flours respectively. All flours were tightly packed in a transparent polythene bag, properly labeled and then stored in air-tight containers for further laboratory use and in the baking of GF cookies production.

Determination of functional properties of flour samples (Bulk Density and Water Absorption Capacity)

Bulk Density (BD) of flour samples was determined as reported by Nwakaudu et al. (2017). Graduated cylinder (100 mL) was weighed dry, and gently filled with flour sample (50 g). The bottom of the cylinder was gently tapped on a laboratory bench until no diminution was observed. The weight of cylinder and flour was noted and recorded. The BD was then calculated as:

BD (g/mL) = sample weight (g)/ sample volume (mL)

The method of Nwakaudu et al. (2017) was adopted to determine the water absorption capacity of the flour samples. One gram (1 g) of sample was mixed with distilled water (10 mL) for 30 seconds in a graduated centrifuged tube. The suspension was left at room temperature for 30 minutes and then centrifuged for 15 minutes at 400 rpm.



a) Biofortified yellow maize grains

b) *Brachystegia eurycoma* seeds

Figure 1: Plant Materials

Determination of Soluble Sugar Content of Flour Samples

The method of Onitilo et al. (2007) was employed to quantify the for soluble sugar contents of the flour samples. In brief, the flour samples (0.02 g) and 80 % hot ethanol (10 mL) were mixed to extract the sugar. Then, the suspension was centrifuged (10 minutes) at 2000 rpm to obtain the supernatant used for estimating the soluble sugar. The soluble sugar content was then quantified by mixing an aliquot (0.2 mL) of the supernatant with 0.5 mL of 0.5 % phenol solution and conc. H_2SO_4 (2.5 mL). It was left at room temperature to cool and then, the absorbance was read at 490 nm. The soluble sugar content was obtained from a glucose standard curve.

Determination of Amylose and Amylopectin Contents of Flour Samples

Juliano *et al.* (1981) method was employed to determine the amylose content of the flour samples. Flour sample (100 mg), 1 mL 100 % (v/v) ethanol and of sodium hydroxide (9 mL) were mixed in a tightly covered 50 mL centrifuged tube. The centrifuged tube containing the samples was then heated (10 minutes) in a boiling water bath to gelatinize the sample's starch. After heating, it was allowed to cool to room temperature then filled to mark with distilled water and thoroughly shaken. Next, the mixture (5 mL) was pipette into volumetric flask (50 mL) followed by the addition of acetic acid (1 mL) and 2 mL of iodine solution before filling to mark with distilled water. A, spectrophotometer was used to take the absorbance of the mixture at 620 nm against reagent blank. Amylose content of the samples was calculated using amylose as a standard. The percentage amylopectin concentration of the sample was calculated as follow: using Amylopectin (%) = 100 − amylose (%) (Juan et al., 2006)

Determination of Pasting Properties

The procedure of Deffenbaugh and Walker, (1989) was adopted to obtain the pasting properties of the flours using Rapid Visco Analyzer (RVA) (model: RVA-4, Perten Scientific, Springfield, IL) equipped to a personal computer with Thermocline software. An aluminum canister was used to prepare a 3 g mixture of flour sample and distilled water (25 mL) and the mixture was then loaded in the RVA. Subsequently, analysis was conducted under constant stirring (160 RPM) by adopting this program: a holding period (5 minutes) at 25°C heating rate (5 °C/minutes) between 25 and 95 °C; a holding period (5 minutes) at 95°C; a cooling rate (5 °C/minutes to 25 °C); and a holding period (5 minutes) at 25°C. Thereafter, the Thermocline software installed on a personal computer system was used to read the pasting properties of the flour samples- peak viscosity, trough, breakdown, final viscosity and set back (expressed in Rapid Visco Analyzer units (RVU) respectively), peak time (minute) and pasting temperature (°C).

Formulation and Baking of Cookies

The procedure of Okaka and Isieh (2002) was adopted to formulate and baked gluten free cookies (GCF) used in this study. Firstly, flour sample (200 g) was mixed with margarine (100 g) using Kenwood Chef to obtain a light and fluffy constituency. . An initial minimum speed was used before increasing the speed step-wisely to the 6 mark on the chef indicator. The flour was then mixed to obtain a stiff paste (batter) using whole egg (60 g), 20 g of powdered milk, baking powder (0.1 g) and 1 g salt. . Thereafter, the batter was rolled on a flour board using rolling pin to a thickness (0.2 to 0.3 cm). The rolled batter was baked (150 °C for 20 minutes) after cutting into shapes and arranged on a greased tray. The baked cookies (Figure 2) were packaged in cellophane bag for further use.

Proximate composition of flour samples and cookies

The procedure of AOAC (2012) was employed to determine the proximate compositions of the samples (flours and cookies) Moisture content was determined by oven drying (105 °C) the samples to a constant weight. Crude fat was extracted with petroleum ether using Soxhlet method. The sample was incinerated (heated) at 525 °C for 4 hours and the residue weight was used to estimate the ash content. Protein content was estimated using Micro-Kjeldahl method and 6.25 was used as the nitrogen conversion factor. The carbohydrate content was obtained by difference.

Sensory Qualities of cookies

Sensory qualities of the freshly baked cookies were evaluated according to the procedure of Ranasalva and Visvanathan (2014). Ethical approval (MOH/KS/EU/777/493) was obtained from Kwara State Ministry of Health, Ilorin. The sensory qualities evaluated were: color, flavor, taste, chewiness and overall acceptability. Twenty panelists comprising of 12 males and 8 females within the age range of 25 – 40 years were given a hedonic scale questionnaire to evaluate the qualities using a 9 points scale [extremely dislike (1), dislike very much (2), dislike moderately (3), dislike slightly (4), neither like nor dislike (5), like slightly (6), like moderately (7), like very much (8), and extremely like (9)].

Data Analysis
The results obtained were expressed as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) using SPSS 21 software. Also, the mean values were compared using Duncan's multiple range tests at 95% confidence level was used to compare the mean.


Figure 2: Gluten-free cookies samples

RESULTS AND DISCUSSION

Functional Properties (Bulk Density and Water Absorption Capacity)
The results of the functional properties (bulk density and water absorption capacity) of the flour samples were showed in Table 1. The bulk density (BD) of 100 % biofortified yellow millet flour (BMF) (1.26 ± 0.00 g/mL) is higher than 100 % white maize flour WMF (1.24 ± 0.00 g/mL) which in turn is higher than 100 % refined wheat flour (RWF) (1.17± 0.00 g/mL). The BD of BMF decrease ($p < 0.05$) has the level of incorporation of BEF and SCMC increased. Similar tread was reported by Irondi et al., (2021) when BEF and SCMC were incorporated in whole millet flour for the production of GF bread. BD is essential in determining product package requirement such that high BD is desirable when considering a reducing in the cost of transportation and packaging of products. Also, higher BD is desired for ease of flours dispensability (Aderinola and Adeoye, 2023). Whereas, low BD is desirable in complementary food formulation. This is because flour particles with lower BD values can stay together at higher amounts thereby increasing the energy contents of their diets (Olosunde et al., 2020).
The water absorption capacity (WAC) of the flour samples ranged from 118.26 ± 0.02% (100% RWF) to 181.30 ± 0.26% (5%BEF-95% BMF). The blend flour with 5 % BEF incorporation (5%BEF-95% BMF, 181.30 ± 0.26%) has higher ($p < 0.05$) WAC value than the other BEF blend. Similarly, the WAC value of 5%SCMC-95% BMF (172.84 ± 0.04 %) was significantly higher ($p < 0.05$) than the other SCMC blends. WAC which can be influenced by the nature of starch (Oluwasina et al., 2019), is an essential functional property in baking (e.g. dough handling) (Nwakaudu et al., 2017) as well as in product’s consistency and bulking (Niba et al., 2001; Friday et al., 2023).

Soluble Sugar, Amylose and Amylopectin Contents of Flour Samples
The result of soluble sugar and percentage amylose and amylopectin contents of the flour samples were showed in Table 1. The level of soluble sugar and percentage amylose and amylopectin contents of 100 % BMF (13.68 ± 0.02 g/100g, 18.31 ± 0.00 %, 81.69 ± 0.00 % respectively) were significantly ($p < 0.05$) influenced by the incorporation of BEF and SCMC respectively. Among the blend flours, 10%BEF-90%BMF has the lowest level of soluble sugar contents (11.07 ± 0.03 g/100g). The amylose content ranged from 1.96± 0.01 (100%BEF) to 44.37± 3.90% (100% SCMC). The flour samples of the 100% flours were in the order of 100% RWF (20.21 ± 1.70 %) > 100% BMF (18.31 ±0.00 %) > 100 % WMF (17.93 ± 0.00%). The amylose and amylopectin contents of 100% BMF (18.31 ±0.00 %, 82.07 ± 0.00 % respectively) and 100% WMF (17.93 ± 0.00 %, 81.69 ± 0.00 % respectively) were within the range of 7 – 35 % (amylose) and 75 – 95 % (amylopectin) previous reported for maize (Li et al., 2018; Qi et al., 2020). The amylose content of BMF significantly decreased ($p < 0.05$) with consistent increase in amylopectin contents as BEF incorporation increased. Whereas, an opposite trend was observed in BMF-SCMC blend as the level of incorporation of SCMC increased. This may be

because of the high level of amylose content in SCMC (44.37 ± 3.90 %) when compared to BMF (18.31 ±0.00 %).

The amylopectin contents of the samples in this study were consistently higher than their corresponding amylose contents. This showed that amylopectin is the dominating starch as previously reported by Yotsawimonwat et al. (2008) and Irondi et al. (2019). Sugar and starch provide energy to the body cells such as the brain cells that solely depend on them for energy (Elemosho et al., 2020). In addition, the ratio of amylose and amylopectin has impact on glycemic index such that a lower amylose and a higher amylopectin concentrations give rise to in a higher glycaemic index (Shanita et al., 2011). This is because alpha-amylase in the human duodenum easily digest amylose and amylopectin. (Birt et al., 2013; Irondi et al., 2021). In addition, they also have influence on the functional properties of flours and their applications in food and industrial products (Irondi et al., 2017).

Pasting Properties of flour samples

Table 2 shows the result of the pasting properties of the flour samples. The pasting properties were in the ranged of 91 (5%SCMC-95% BMFBMF) to 14708 (100% SCMC), 81 (5%SCMC-95% BMFBMF) to 12772 (100% SCMC), 10 (5%SCMC-95% BMFBMF) to 2410 (100% BEF), 32 (5%SCMC-95% BMFBMF) to 6120 (100%BEF) and 113 (5%SCMC-95% BMFBMF) to 17673 (100% SCMC) (RVU respectively) for peak, trough, breakdown, setback and final viscosities respectively. The peak time of 100% BEF, BEF-BMFBMF blend and 5%SCMC-95%BMFBMF were significantly ($p < 0.05$) comparable (7.0 minutes) and 100% WMF has the lowest peak time (4.93 minutes). Pasting temperature ranged from 50.05 (100% SCMC) to 92.05 °C (5%BEF-95% BMFBMF). Among the blends, 7.5%SCMC-92.5%BMFBMF blend has the lowest pasting temperature (79.15 °C) and therefore may need the lowest energy to cook. As reported by (Elemosho et al., 2020), the lower the pasting temperature, the lower the energy cost required fora flour sample cooking.

The differences in the pasting properties of the flour samples particularly the maize flours may be related to differences in starch composition (Ortiz et al., 2019). Pasting properties refer to the chemical and physical structures of starch in dispersion that change during a certain cycle of heating and cooling under shear forces (Liao and Wu, 2016; Irondi et al., 2017). They played important roles in starch's industrial application like food industry (Berski et al., 2011), and are linked to starch's water binding capacity as well as the expansion of its granules after heating (Owuno and Achinewhu, 2021). The peak and final viscosities are the most vital pasting parameter for the food industries (Irondi et al., 2018). Final viscosities show the durability of cooked starch and the paste's resistance to shear force during stirring (Irondi et al., 2021).

Table 1: Functional Properties of Flour Samples

Samples	BD (g/mL)	%WAC	Soluble sugar (g/100g)	%Amylopectin	% Amylose
100% BMF	1.26±0.00^{m}	170.53± 0.00^{c}	13.68 ± 0.02^{j}	81.69±0.00^{f}	18.31±0.00^{c}
100% RWF	1.17±0.00^{d}	118.26±0.02^{a}	10.25 ± 0.03^{c}	76.19±1.70^{g}	20.81±1.70^{b}
100% WMF	1.24±0.00^{k}	164.90± 0.20^{c}	10.80 ± 0.01^{d}	82.07±0.00^{i}	17.93±0.00^{a}
100% BEF	1.23±0.00^{i}	174.41±0.06^{cd}	7.94 ± 0.12^{b}	98.04±0.00^{e}	1.96±0.00^{d}
100% SCMC	1.19±0.00^{e}	150.14±0.02^{b}	5.82 ± 0.04^{a}	55.62±3.90^{b}	44.37±3.90^{g}
2.5%BEF-97.5% BMF	1.22±0.00^{g}	151.26±0.00^{b}	12.85 ± 0.00^{h}	91.94±0.24^{c}	8.06±0.24^{f}
5%BEF-95% BMF	1.25±0.00^{l}	181.30±0.26^{d}	12.13 ± 0.14^{f}	89.11.10±0.97^{a}	10.89±0.97^{h}
7.5%BEF-92.5% BMF	1.17±0.00^{c}	144.14±0.05^{b}	12.00 ± 0.03^{f}	87.63±0.00^{f}	12.37±0.00^{c}
10%BEF-90%BMF	1.22±0.00^{f}	121.66±0.03^{a}	11.07 ± 0.03^{e}	86.97±1.95^{g}	13.03±1.95^{b}
2.5%SCMC-97.5% BMF	1.16±0.00^{b}	164.59±0.10^{c}	13.00 ± 0.02^{i}	71.31±0.24^{d}	28.68±0.24^{e}
5%SCMC-95% BMF	1.22±0.00^{h}	172.84±0.04^{cd}	13.87 ± 0.00^{k}	78.72±1.46^{e}	21.27±1.46^{d}
7.5%SCMC-92.5%BMF	1.16±0.00^{a}	165.78±0.05^{c}	12.79 ± 0.10^{h}	62..87±0.00^{h}	37.13±0.00^{i}
10%SCMC-90% BMF	1.23±0.00^{j}	126.58±0.08^{a}	12.44 ± 0.01^{g}	59.65±0.00^{g}	40.65±0.00^{b}

Data are expressed as the mean values ± standard deviation (SD). Value with different superscript letters along the same column vary significantly ($p < 0.05$). BYM, biofortified yellow maize flour; RWF, refined wheat flour; WMF, white maize flour; SCMC, sodium carboxylmethyl cellulose, BEF, *Brachystegia eurycoma* flour, BD, bulk density, WAC. Water absorption capacity

Table 2: Pasting Properties of Flour Samples

Samples	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Setback (RVU)	Final viscosity (RVU)	Peak time (Min)	Pasting temp (℃)
100%BMFBMF	332^{b}	304^{c}	28^{a}	672^{d}	976^{b}	6.93^{d}	91.25^{c}
100% RWF	1007^{c}	662^{d}	345^{c}	789^{d}	1451^{c}	5.67^{b}	87.3^{c}
100%WMF	608^{c}	495^{c}	113^{b}	932^{d}	1427^{c}	4.93^{a}	82.3^{b}
100% BEF	5204^{d}	2794^{e}	2410^{d}	6102^{e}	8896^{e}	7.0^{d}	88.7^{c}
100% SCMC	14708^{e}	12772^{f}	1936^{d}	4901^{e}	17673^{f}	6.0^{c}	50.05^{a}
2.5%BEF-97.5% BMFBMF	529^{b}	473^{c}	56^{a}	1047^{d}	1520^{c}	7.0^{d}	87.2^{b}
5%BEF-95% BMFBMF	393^{b}	334^{c}	59^{a}	887^{d}	1221^{c}	7.0^{d}	92.05^{c}
7.5%BEF-92.5% BMFBMF	555^{b}	446^{c}	109^{b}	1354^{e}	1800^{c}	7.0^{d}	89.6^{c}
10%BEF-90%BMFBMF	831^{c}	652^{d}	179^{b}	1904^{e}	2556^{d}	7.0^{d}	86.4^{c}
2.5%SCMC-97.5% BMFBMF	165^{a}	152^{a}	13^{a}	94^{b}	246^{a}	7.0^{d}	88.1c
5%SCMC-95% BMFBMF	91^{a}	81^{a}	10^{a}	32^{a}	113^{a}	6.4^{c}	88.1^{c}
7.5%SCMC-92.5%BMFBMF	505^{b}	463^{b}	42^{a}	317^{c}	780^{b}	-	79.15^{b}
10%SCMC-90% BMFBMF	281^{a}	262^{b}	19^{a}	124^{b}	386^{a}	-	87.28^{c}

Data are expressed as the mean values ± standard deviation (SD). Value with different superscript letters along the same column vary significantly ($p < 0.05$). BYM, biofortified yellow maize flour; RWF, refined wheat flour; WMF, white maize flour; SCMC, sodium carboxylmethyl cellulose, BEF, *Brachystegia eurycoma* flour

Proximate composition of flour and cookies samples

Table 3 and 4 presented the result of the proximate composition of the flour and cookies samples respectively. The results showed that the flours and cookies have a significant ($p < 0.05$) level of nutritional composition. SCMC (synthetic hydrocolloid) has the lowest level ($p < 0.05$) of moisture content (3.97 ± 0.01 %), crude protein (1.09 ± 0.00 %), total ash (0.86 ± 0.01 %), crude fat (0.01 ± 0.0 %) and crude fibre (0.02 ± 0.00%). Whereas, has the highest level of total carbohydrate (94.04 ± 0.02 %) and food energy (380.65 ± 2.91 kg/cal). The moisture content of 100% BMFBMF (6.25 ± 0.06 %) is significantly higher ($P < 0.05$) than the 100% WMF (5.91± 0.12 %). However, 100% WMF has significantly higher ($P < 0.05$) level of total carbohydrate (80.78 ±0.18 %) and food energy (376.01 ± 1.04 kg/cal) than 100% BMFBMF (74.76 ±0.14 %, 370.05 ± 2.09 kg/cal respectively). Further, their total ash content (100% BMFBMF, 1.05 ± 0.04 % and 100%WMF, 1.06 ± 0.01 % were significantly comparable. The crude protein content of 100% BEF which has been identified as a leguminous crop (Nwakaudu *et al.*, 2017) is 12.02 ± 0.00 %. Among all the flour samples, 100% BMFBMF has the highest level of crude protein (12.78±0.08 %) and fibre (2.94 ± 0.12 %) but the lowest total carbohydrate (74.76 ± 0.14 %).

Further, The GF cookies had moisture content ranging from 7.65 ± 0.41 % (10%SCMC-90%BMF) to 10.93 ± 0.03 % (100% BMF), crude protein ranging from 6.65 ± 0.00 % (2.5%BEF-97.5%BMF) to 8.56 ± 0.03 % (7.5%BEF-92.5%BMF), a range from 0.28 ± 0.21 % (10%BEF-90%BMF) to 3.16 ± 0.01 % (10%SCMC-90%BMF) for total ash, 18.90± 0.38 % (10%BEF-90%BMF) to 28.72 ± 0.50 % (5%SCMC-95%BMF) for crude fat, 50.85 ± 0.55 % (10%SCMC-90%BMF) to 60.26 ± 0.77 % (10%BEF-90%BMF) for total carbohydrate and 445.31 ± 0.77 kg/cal (7.5%BEF-92.5%BMF) to 507.12 ± 0.80 kg/cal (2.5%BEF-97.5%BMF) for food energy. The total carbohydrate of 10%BEF-90%BMF (60.26 ±0.77%) and 7.5%BEF-92.5%BMF (60.21 ± 1.08%) were significantly ($p < 0.05$) comparable. The moisture and crude fat content of GF cookies samples were higher ($p < 0.05$) than their corresponding flour samples

Table 3: Proximate Composition of Flour Samples

Sample	Moisture content (%)	Crude protein (%)	Total ash (%)	Crude fibre (%)	Crude fat (%)	Total carbohydrate (%)	Food energy (kg/cal)
100%BMF	$6.25±0.06^{def}$	$12.78 ± 0.08^{l}$	$1.05 ± 0.04^{b}$	$2.94 ± 0.12^{h}$	$2.21 ± 0.08^{g}$	$74.76 ± 0.14^{a}$	$370.05 ± 2.09^{a}$
100% RWF	$5.54±0.02^{b}$	$11.01 ± 0.04^{g}$	$1.85 ± 0.15^{e}$	$1.06 ± 0.02^{c}$	$1.79 ± 0.09^{d}$	$78.73 ± 0.24^{g}$	$375.15 ± 3.11^{c}$
100%WMF	$5.91 ± 0.12^{c}$	$9.61 ± 0.01^{f}$	$1.06 ± 0.01^{b}$	$1.14 ± 0.02^{c}$	$1.69 ± 0.00^{c}$	$80.58 ± 0.18^{i}$	$376.01 ± 1.04^{c}$
100% BEF	$5.24 ± 0.02^{b}$	$12.02 ± 0.00^{j}$	$1.95 ± 0.12^{e}$	$0.58 ± 0.01^{b}$	$0.72 ± 0.01^{b}$	$79.48 ± 0.08^{h}$	$372.50 ± 0.43^{b}$
100% SCMC	$3.97 ± 0.01^{a}$	$1.09 ± 0.00^{a}$	$0.86 ± 0.01^{a}$	$0.02 ± 0.00^{a}$	$0.01 ± 0.0^{a}$	$94.04 ± 0.02^{j}$	$380.65 ± 2.91^{d}$
2.5%BEF-97.5% BMF	$6.39 ± .021^{efg}$	$11.99 ± 0.02^{i}$	$1.69 ± 0.01^{d}$	$2.35 ± 0.01^{g}$	$2.54 ± 0.02^{h}$	$75.04 ± 0.01^{b}$	$370.98 ± 0.24^{a}$
5%BEF-95% BMF	$6.67 ± 0.31^{g}$	$12.59 ± 0.0^{k}$	$1.52 ± 0.00^{c}$	$2.16 ± 0.04^{f}$	$2.11 ± 0.02^{f}$	$74.94 ± 0.15^{ab}$	$369.17 ± 1.63^{a}$
7.5%BEF-92.5% BMF	$6.13 ± 0.21^{cde}$	$11.64 ± 0.01^{h}$	$1.58 ± 0.02^{cd}$	$2.06 ± 0.02^{de}$	$1.95 ± 0.02^{e}$	$76.62 ± 0.02^{de}$	$370.61 ± 2.33^{a}$
10%BEF-90%BMF	$6.00 ± 0.63^{cd}$	$12.48 ± 0.02^{j}$	$1.48 ± 0.04^{c}$	$2.02 ± 0.00^{d}$	$1.62 ± 0.02^{c}$	$76.38 ± 0.02^{d}$	$370.04 ± 2.94^{a}$
2.5%SCMC-97.5% BMF	$6.27 ± 0.03^{def}$	$7.66 ± 0.01^{b}$	$2.99 ± 0.02^{f}$	$2.05 ± 0.14^{d}$	$3.52 ± 0.04^{i}$	$77.50 ± 0.03^{f}$	$372.34 ± 4.31^{b}$
5%SCMC-95% BMF	$6.49 ± 0.01^{fg}$	$7.99 ± 0.04^{c}$	$3.04 ± 0.00^{f}$	$2.21 ± 0.02^{f}$	$3.64 ± 0.00^{j}$	$76.62 ± 0.04^{de}$	$371.24 ± 5.02^{a}$
7.5%SCMC-92.5%BMF	$6.07 ± 0.32^{cd}$	$8.54 ± 0.02^{e}$	$3.38 ± 0.09^{g}$	$2.36 ± 0.01^{g}$	$4.11 ± 0.01^{l}$	$75.58 ± 0.09^{c}$	$373.49 ± 2.71^{b}$
10%SCMC-90% BMF	$5.54 ± 0.02^{b}$	$8.11 ± 0.05^{d}$	$3.32 ± 0.00^{g}$	$2.14 ± 0.01^{ef}$	$3.88 ± 0.01^{k}$	$76.78 ± 0.02^{e}$	$374.50 ± 1.32^{c}$

Data are expressed as the mean values ± standard deviation (SD). Value with different superscript letters along the same column vary significantly ($p < 0.05$). BYM, biofortified yellow maize flour; RWF, refined wheat flour; WMF, white maize flour; SCMC, sodium carboxylmethyl cellulose, BEF, *Brachystegia eurycoma* flour

Table 4: Proximate composition of cookies

Samples	Moisture (%)	Crude protein (%)	Total ash (%)	Crude fat (%)	Total carbohydrate (%)	Food Energy (cal/100g)
100% BMF	$10.93 ±0.03^{f}$	$7.71 ±0.27^{bc}$	$1.65 ± 0.28^{bc}$	$21.23 ±0.19^{b}$	$59.22 ± 0.21^{d}$	$458.84 ± 2.04^{b}$
100% RWF	$9.52 ±0.14^{de}$	$7.42 ± 0.07^{b}$	$1.32 ± 1.52^{ab}$	$24.69 ± 1.27^{c}$	$56.04 ±1.08^{c}$	$476.07±7.4^{c}$
2.5%BEF-97.5% BMF	$8.38 ± 0.24^{bc}$	$6.65 ± 0.00^{a}$	$2.10 ±0.09^{bcd}$	$29.82 ± 0.29^{e}$	$53.03 ± 0.45^{b}$	$507.12±0.80^{f}$
5%BEF-95% BMF	$8.62 ± 0.47^{bc}$	$7.53 ± 0.10^{bc}$	$2.48 ±0.16^{bcd}$	$24.38 ± 0.55^{c}$	$56.97 ± 0.19^{c}$	$477.45 ± 5.31^{cd}$
7.5%BEF-92.5% BMF	$9.61 ± 0.50^{e}$	$8.56 ± 0.03^{d}$	$2.69 ± 0.16^{cd}$	$18.90 ± 0.38^{a}$	$60.21 ± 1.08^{d}$	$445.31 ± 0.77^{a}$
10%BEF-90%BMF	$8.01± 0.12^{ab}$	$7.65 ± 0.18^{bc}$	$0.28 ± 0.21^{a}$	$23.79± 0.69^{c}$	$60.26 ± 0.77^{d}$	$485.74 ± 3.90^{de}$
2.5%SCMC-97.5% BMF	$8.92 ± 0.08^{cd}$	$7.84 ± 0.00^{c}$	$2.58 ± 0.19^{cd}$	$23.49 ± 0.61^{c}$	$57.15 ± 0.89^{c}$	$471.47 ± 1.97^{c}$
5%SCMC-95% BMF	$10.06± 0.04^{e}$	$7.77 ± 0.19^{bc}$	$2.73 ± 0.02^{cd}$	$28.72 ± 0.50^{e}$	$50.85± 0.55^{a}$	$493.05±1.50^{e}$
7.5%SCMC-92.5%BMF	$9.62 ± 0.27^{e}$	$7.42 ± 0.13^{b}$	$2.86 ± 0.18^{cd}$	$20.55 ± 0.42^{b}$	$59.53 ± 1.02^{d}$	$452.32 ± 0.42^{ab}$
10%SCMC-90% BMF	$7.65 ± 0.41^{a}$	$7.33 ± 0.18^{e}$	$3.16 ± 0.01^{d}$	$26.16 ± 0.72^{d}$	$55.69 ± 0.46^{ab}$	$487.54 ± 5.34^{e}$

Data are expressed as the mean values ± standard deviation (SD). Value with different superscript letters along the same column vary significantly ($p < 0.05$). BYM, biofortified yellow maize flour; RWF, refined wheat flour; SCMC, sodium carboxylmethyl cellulose, BEF, *Brachystegia eurycoma* flour

Moisture contents served as an important parameter in food preservation, shelf-life as well as storage stability. It affects deterioration rate and subsequently the product quality. The, total carbohydrate, crude fat and crude protein served as a source of energy whereas, the total ash content served as the indicator of mineral contents of food samples (Aderinola and Adeoye, 2023). Also crude proteins will serve as a source of important amino acid which will be require for body functions like the repair and growth of body cell as well as tissues (Cruzat et al., 2018). Further, crude fibre is an indication of the present of dietary fibre in the samples. It can aid in reducing constipation, colon cancer, risks of coronary heart diseases, type-2 diabetes and obesity (Okereke et al., 2021; Imam et al., 2024).

Sensory qualities of the cookies samples

The perception of the sensory panelists on the sensory qualities (taste, color, appearance, aroma, crispiness, texture and overall acceptability) of the cookies was presented in table 5. The result revealed that the taste of 100% RWF cookies is significantly ($p < 0.05$) comparable with BMFBMF10%BEF-90%BMF, 7.5%BEF-92.5%BMF, 5%BEF-95%BMF, and 10%SCMC-90%BMF. Likewise, the taste of 100%BMF, 2.5%BEF-97.5%BMF, BMF5%SCMC-90%BMF and 7.5%SCMC-92.5%BMF cookies are also significantly comparable ($p > 0.05$). The cookies of 100% RWF showed the lowest value for appearance (7.2 ± 1.02) and color (7.2 ± 0.75). BMF and its blend may be more attractive to the panelist due to its yellowish coloration. Color served an important quality parameter that makes cookies charming. The color formation is influence by the flour and starch used in baking cookies (Elif and Duygu, 2020). In bakery, the color of the final product can also be influenced by Maillard reaction (Giuberti et al., 2018). The overall acceptability of 100%BMF (7.88 ± 1.15) and 100% RWF (7.90 ± 1.05) were significantly comparable ($p > 0.05$). As observed in most of the cookies blend, the addition of BEF and SCMC further enhanced the overall acceptability of BMF respectively.

Table 5: Sensory Qualities of the Cookies

Samples	Taste	Appearance	Color	Crispiness	Aroma	Overall acceptability	Texture
100%BMF	7.70 ± 1.65^{c}	8.29 ± 1.45^{b}	8.11 ± 1.23^{c}	7.35 ± 1.15^{a}	7.82 ± 0.85^{c}	7.88 ± 1.15^{b}	7.23 ± 1.15^{a}
100% RWF	7.10 ± 1.23^{a}	7.20 ± 1.02^{a}	7.20 ± 0.75^{a}	7.10 ± 2.05^{b}	7.65 ± 1.08^{a}	7.90 ± 1.05^{b}	7.70 ± 0.8^{c}
2.5%BEF-97.5% BMF	7.90 ± 1.08^{c}	8.00 ± 0.00^{b}	8.10 ± 1.11^{c}	7.35 ± 1.20^{b}	7.45 ± 1.25^{a}	8.40 ± 1.20^{c}	7.90 ± 1.25^{d}
5%BEF-95% BMF	7.20 ± 2.28^{a}	7.25 ± 1.25^{b}	7.50 ± 1.25^{a}	7.25 ± 0.75^{b}	7.40 ± 1.50^{a}	7.60 ± 1.50^{a}	7.20 ± 1.25^{a}
7.5%BEF-92.5% BMF	7.00 ± 0.00^{a}	8.00 ± 0.00^{b}	7.75 ± 0.75^{b}	7.20 ± 0.84^{b}	7.50 ± 0.95^{b}	8.10 ± 2.10^{c}	7.45 ± 1.05^{b}
10%BEF-90%BMF	7.15 ± 1.89^{a}	7.95 ± 0.75^{b}	8.10 ± 1.25^{c}	7.65 ± 1.25^{bc}	7.55 ± 1.65^{b}	7.90 ± 1.25^{b}	7.65 ± 1.08^{a}
2.5%SCMC-97.5% BMF	7.40 ± 2.04^{b}	8 ± 15.28^{b}	8.15 ± 1.05^{c}	6.65 ± 1.97^{a}	7.60 ± 0.75^{b}	7.95 ± 1.26^{b}	7.60 ± 1.05^{c}
5%SCMC-95% BMF	7.80 ± 2.34^{c}	7.95 ± 0.75^{b}	8.10 ± 1.05^{c}	7.25 ± 0.75^{b}	7.85 ± 1.05^{c}	7.95 ± 0.65^{b}	7.55 ± 1.05^{b}
7.5%SCMC-92.5%BMF	7.80 ± 1.24^{c}	8.05 ± 1.28^{b}	7.75 ± 0.50^{b}	7.10 ± 1.62^{a}	7.65 ± 1.15^{a}	7.90 ± 0.21^{b}	7.20 ± 0.85^{a}
10%SCMC-90% BMF	7.25 ± 2.18^{a}	7.95 ± 1.35^{b}	8.10 ± 1.24^{c}	7.95 ± 1.22^{c}	7.60 ± 0.75^{a}	7.75 ± 1.05^{a}	7.60 ± 1.10^{c}

Data are expressed as the mean values ± standard deviation (SD). Value with different superscript letters along the same column vary significantly ($p < 0.05$BYM, biofortified yellow maize flour; RWF, refined wheat flour; SCMC, sodium carboxylmethyl cellulose, BEF, *Brachystegia eurycoma* flour

CONCLUSION

The incorporation of *Brachystegia eurycoma* flour (BEF) has a significant ($p < 0.05$) effect on the physicochemical properties of biofortified yellow maize flour (BMF) and on the proximate composition and sensory qualities of their GF cookies. It significantly ($p < 0.05$) decreased the bulk density, water absorption capacity, soluble sugar and amylose content of BMF as its amount of incorporation increased. The pasting properties of BMF blends were higher than the 100% BMF except for pasting temperature. The flour and cookies samples demostrated a notable ($p < 0.05$) amount of proximate composition. Although, the cookies had much y higher ($p < 0.05$) moisture and crude protein contents of than their corresponding flour samples, which might beattributed to the baking process, the dough's water holding capacity and the ingredients used. The cookies samples have a significant sensory rating, with 2.5%BEF-97.5% BMF cookies have the highest over acceptability value among the samples. Therefore, adding BEF enhanced the physicochemical and sensory qualities of GF cookies baked from biofortified yellow maize flour.

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