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Cookies-making potentials of sorghum-wheat flour blends

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ABSTRACT

Background: Composite flours provide possibilities in enhancing the nutritional and quality characterises of baked foods.
Objectives: In this study, the proximate, functional and pasting characteristics of sorghum-wheat composite flours consisting of 20 % and 40 % sorghum flour substitution levels were investigated.
Methods: The sorghum-wheat composite flours were utilised in the production of cookies and their proximate and sensory acceptability were examined.
Results: It was revealed that an increase in sorghum flour levels in the composite flours increased ash, crude fibre, carbohydrates (2.62% and 3.95%) and dry-matter (8%) while decreasing protein and fat compositions. Also, increase in bulk density (5% and 9%), water absorption (24% and 31%), swelling power, solubility, peak viscosity (52% and 37%), breakdown viscosity and setback viscosity of the composite flour increased with increase in sorghum flour levels. Cookies produced from the composite flours showed increased protein contents. Consumers preferred the colour, appearance and taste of cookies produced from composite flour containing 40% sorghum flour than that of wheat flour cookie.
Conclusions: This study has demonstrated the baking functionality and nutritional qualities of sorghum-wheat composite flour.

Keywords: Sorghum; Cookies; Baking functionality; Pasting characteristics; Swelling power

INTRODUCTION

Cookies are a class of baked foods that are characterised by high flour, sugar and shortenings composition and low moisture content (Xu *et al*., 2020). Due to their indulgent nature, high popularity, relatively low cost and high shelf-life stability, they provide a potential means of enhancing nutritional enrichment of the populace in developing countries (Rao *et al*., 2018). Based on consumer acceptability, wheat flour is regarded as the benchmark flour for cookies production (Adeyeye, 2016; Esan *et al*., 2017). However, celiac disease including the high market price, importation and processing costs of wheat incurred by importing countries has necessitated the need to utilise gluten-free flours for the production of cookies.

Sorghum flour is an underutilised cereal flour that has a nutritional profile and functional characteristics suitable for bakery application. It is rich in energy, protein, vitamins (B-vitamins), minerals (iron and zinc), fibre, carbohydrates and has high amylopectin to amylose ratio (70:30 or 80:20) (Ibrahim & Ani, 2018; Rao *et al*., 2018).When utilised in the production of cookies, sorghum flour produces a smoother textured product when compared with rice flour (Adeyeye, 2016).

Due to its gluten-free nature, sorghum flour produces inferior baked products when compared with wheat flour. Wheat-based composite flours have been shown to improve the baking inadequacy of flours. This is evident from studies which revealed that blending rice flour and maize flour with wheat flour, respectively, resulted in cookies with better quality characteristics than those produced from rice flour and maize flours (Awofadeju & Olapade, 2020; Kaur & Gill, 2020).

The cookie-making potentials of sorghum-wheat composite flours containing 20% and 40% sorghum flour substitution levels were evaluated using their proximate composition, functional characteristics, and pasting characteristic of the flour, as well as the sensory acceptability of cookies produced from the different composite flours.

Materials and methods

Experimental materials

White sorghum grains (*Sorghum bicolor*) were sourced from a local market in Ota, Nigeria. Commercial wheat flour (Golden Penny), sugar (Dangote), margarine (Topper), whole milk powder (Peak), and table salt (Dangote) were purchased from a local supermarket in Ota, Nigeria.

Flour preparation

Sorghum grains were sorted, washed and dried at 65 ºC for 14 h in a convection oven. The dried sorghum grains were dry-milled and passed through a 100-micron sieve. Sorghum flour at 20% and 40% substitution levels were properly blended with wheat flour. The sorghum-wheat composite flours were stored in dry air-tight bags at ambient conditions for further analyses.

Cookies preparation

Margarine (110 g) was mixed with sugar (50 g) until the right consistency was achieved. The mixture was then mixed with whole milk powder (5 g), salt (1 g) and flour (200 g). The dough was thoroughly kneaded, shaped into uniform slices and baked at 195 °C for 18 mins. The cookies were cooled to ambient temperature and stored in airtight bags at ambient conditions for further analyses.

Proximate analysis

The proximate composition of samples namely dry matter, protein, fat, ash, crude fibre and carbohydrates were determined using the methods described by AOAC (2010).

Bulk density

Bulk density of Sorghum-wheat composite flour was determined following the method described by *(Yu et al.*, 2018) with slight modification. Sample (2.5 g) was filled in a 10mL graduated cylinder and its bottom tapped on the laboratory bench until there was no decrease in volume of the sample. The volume was calculated as follows:

$$\text{Bulk density}\left(\frac{g}{mL}\right) = \frac{\text{Weight of sample}}{\text{Volume of sample}}$$

Water absorption capacity

Samples (1 g) were weighed into 15mL centrifuge tubes and distilled water (10 mL) was added to the tubes, followed by vortexing for 5mins, and centrifuging at 3500 ×g for 30mins. Suspending liquid phases were discarded and tubes containing swollen samples were weighed. Water and oil absorption capacity calculated as follows:

$$\text{Water absorption capacity}\left(\frac{g}{g}\right) = \frac{\text{Weight of swollen sample}}{\text{Weight of dry sample}}$$

Swelling power and solubility

The swelling power and solubility of samples were determined in triplicate, following the method described by Duduet *al.* (2019). Flour samples (0.1g) were weighed into 15 mL centrifuge tubes followed by the addition of distilled water (10mL). The tubes were gently vortexed for 5 min and heated at 95°C for 30 mins respectively in a water bath (with intermittent shaking). The tubes were cooled to ambient temperature and centrifuged at 3500 × g for 20 mins. Aliquots of supernatants were transferred into dried moisture cans and dried at 105°C to constant weight. Swelling power and solubility were calculated as follows:

$$\text{Swelling power}\left(\frac{g}{g}\right)=\frac{\text{Weight of swollen sample}}{\text{Weight of sample-Weight of residue}}$$

$$\text{Solubility (\%)} = \frac{\text{Weight of residue}}{\text{Weight of dry sample}} \times 100$$

Pasting characteristics

Pasting characteristics of samples were determined using a rapid visco-analyser. Samples (3.5 g) were suspended in distilled water (25mL) and subjected to the following at a constant rotating speed of 160 rpm throughout the process: mixing for1 min, heating from 50 °C to 95 °C (3.5 mins), isothermal heating at 95 °C (2.5 mins), cooling from 95 °C to 50 °C (4 mins) and isothermal heating at 50 °C (2 mins). Pasting characteristics of the samples data were retrieved from the rapid visco-analyser.

Sensory evaluation

Multiple Comparison Test method using hedonic scale rating was used to investigate the differences in sensory characteristics of cookies produced from wheat flour and the sorghum-wheat composite flours. A panel of 30 judges was used for the sensory evaluation. Cookie samples were coded with three random characters and presented to each panelist in random order. Each judge was presented with a questionnaire requesting them to detect differences among samples with regards to colour, appearance, taste, aroma, texture, mouth-feel and crispiness and overall acceptability. This was achieved by using a 9-point hedonic scale rating, where point "9" indicated extreme likeness and point "1" indicated extreme dislike (Ihekoronye & Ngoddy, 1985).

Statistical analysis

Triplicate data from all the analyses were analysed using the Statistical Package for the Social Sciences (SPSS, version 26.0, USA). Data means were compared with the aid of a one-way analysis of variance (ANOVA) using a significance level of $P < 0.05$. Duncan's post hoc test was used in describing and characterising the differences among the datasets.

Results and discussion

Functional characteristics of composite flour

The functional characteristics of wheat flour and composite flours consisting of different sorghum substitution levels are shown in Table 1. The incorporation of sorghum flour into the wheat flour matrix had a positive effect on all studied functional characteristics.

Composite flour consisting of 20% and 40% sorghum flour substitution levels had 5% and 9% higher bulk densities than wheat flour, which was due to sorghum flour's 13% higher bulk density when compared with wheat flour. The addition of sorghum flour into the wheat flour matrix increased granule compactness due to the increased amount of small granules, thus increasing bulk density (Adebayo-Oyetoro *et al.*, 2017; Ahmed *et al.*, 2014). The high bulk density property of sorghum flour and sorghum-wheat composite flours suggests that could function as good food thickeners which is suitable for cookies production (Abe-Inge *et al.*, 2020).

When compared to wheat flour, composite flours with 20% and 40% sorghum flour substitutions had 24% and 31% higher water absorption, respectively, due to sorghum flour's 42 % higher water absorption. The presence of sorghum flour in the wheat flour matrix incorporated more polar or charged side-chained hydrophilic components (Ofori et al., 2020). (Ofori et al., 2020). The increase in the water absorption property of the sorghum-wheat composite flours could be advantageous, increasing the consistency of biscuit batter (Paesani et al., 2020).

Furthermore, composite flour containing 20% and 40% sorghum flour substitutions had 5% and 1% higher swelling powers than wheat flour. Moreover, sorghum flour had 4% lower swelling power when compared with wheat flour. Swelling power is the ability of flour granules to absorb water

Table 1 Functional characteristics of sorghum-wheat composite flours

Samples	Bulkdensity (g/mL)	Water absorption (g/g)	Swelling power (g/g)	Solubility(%)
WF	0.68 ± 0.01^{a}	$1.47.07\pm0.02^{bc}$	4.59 ± 0.06^{a}	5.79 ± 0.09^{a}
SF	0.78 ± 0.01^{a}	2.54 ± 0.02^{a}	4.40 ± 0.03^{a}	3.51 ± 0.01^{b}
SWF1	0.71 ± 0.01^{a}	1.83 ± 0.024^{b}	4.80 ± 0.22^{a}	6.19 ± 0.10^{a}
SWF2	0.74 ± 0.01^{a}	1.92 ± 0.02^{b}	4.62 ± 0.14^{a}	6.33 ± 0.02^{a}

Values presented are mean ± standard deviation of triplicate experiments. Means within a column with different superscripts are significantly different (P <0.05).WF, wheat flour; SF, sorghum flour; SWF1, 20% sorghum flour +80% wheat flour and SWF2, 40% sorghum flour +60% wheat flour.

Table 2 Pasting characteristics of sorghum-wheat composite flours

Samples	Pasting temperature (°C)	Peak viscosity (RVU)	Holding viscosity (RVU)	Final viscosity (RVU)	Breakdown viscosity (RVU)	Setback viscosity (RVU)
WF	83.45 ± 0.01^{b}	215.34 ± 0.01^{c}	200.68 ± 0.01^{c}	271.92 ± 0.01^{c}	14.66 ± 0.01^{d}	71.24 ± 0.01^{c}
SF	64.51 ± 0.01^{c}	178.32 ± 0.01^{d}	160.50 ± 0.01^{d}	198.92 ± 0.01^{d}	17.82 ± 0.01^{c}	38.42 ± 0.01^{d}
SWF1	84.22 ± 0.02^{a}	327.52 ± 0.02^{a}	265.66 ± 0.01^{a}	412.83 ± 0.01^{a}	61.83 ± 0.01^{a}	147.18 ± 0.02^{a}
SWF2	64.95 ± 0.01^{c}	295.22 ± 0.03^{b}	244.82 ± 0.01^{b}	386.25 ± 0.01^{b}	50.40 ± 0.01^{b}	141.43 ± 0.01^{b}

Values presented are mean ± standard deviation of triplicate experiments. Means within a column with different

Table 3 Proximate composition of sorghum-wheat composite flours and cookies

Samples		Dry matter (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Crude fibre(%)	Carbohydrate (%)
Flour							
	WF	97.98 ± 0.05^{a}	16.03 ± 0.05^{a}	2.62 ± 0.02^{b}	0.60 ± 0.01^{ab}	0.76 ± 0.05^{b}	67.99 ± 0.04^{d}
	SF	90.37 ± 0.05^{c}	9.19 ± 0.03^{d}	2.15 ± 0.02^{b}	1.13 ± 0.03^{a}	2.06 ± 0.02^{a}	75.86 ± 0.10^{a}
	SWF1	89.80 ± 0.05^{b}	14.63 ± 0.13^{b}	2.58 ± 0.04^{a}	0.79 ± 0.03^{a}	0.98 ± 0.02^{b}	70.61 ± 0.21^{c}
	SWF2	89.63 ± 0.03^{b}	13.22 ± 0.08^{c}	2.18 ± 0.03^{b}	0.94 ± 0.03^{a}	1.67 ± 0.04^{a}	71.91 ± 0.11^{b}
Biscuit							
	WF	98.01 ± 0.01^{b}	9.29 ± 0.01^{b}	31.50 ± 0.02^{b}	2.89 ± 0.02^{a}	5.53 ± 0.01^{a}	48.82 ± 0.02^{b}
	SWF1	97.26 ± 0.01^{a}	10.12 ± 0.02^{a}	28.11 ± 0.01^{c}	2.99 ± 0.01^{a}	5.17 ± 0.02^{a}	50.88 ± 0.02^{a}
	SWF2	97.43 ± 0.01^{a}	9.60 ± 0.02^{b}	34.84 ± 0.01^{a}	2.19 ± 0.02^{b}	5.62 ± 0.01^{a}	45.20 ± 0.04^{c}

Values presented are mean ± standard deviation of triplicate experiments. Means within a column with different superscripts are significantly different (P <0.05).WF, wheat flour; SF, sorghum flour; SWF1, 20% sorghum flour +80% wheat flour and SWF2, 40% sorghum flour +60% wheat flour.

Table 4 Sensory evaluation of cookies from wheat flour and sorghum-wheat composite flours

Samples	Colour	Appearance	Taste	Aroma	Texture	Mouthfeel	Crispiness	Overall acceptability
WF	6.25±0.48^{a}	6.42±0.29^{a}	5.92±0.53^{b}	6.67±0.26^{a}	5.92±0.36^{a}	6.50±0.38^{a}	6.33±0.42^{b}	6.25±0.39^{b}
SWF1	6.50±0.45^{a}	6.67±0.40^{a}	6.50±0.38^{a}	6.67±0.41^{a}	6.08±0.48^{a}	6.25±0.43^{a}	6.33±0.50^{b}	6.83±0.40^{a}
SWF2	6.25±0.46^{a}	6.50±0.40^{a}	5.58±0.56^{c}	6.08±0.43^{b}	6.17±0.37^{a}	6.33±0.45^{a}	7.17±0.32^{a}	6.25±0.45^{b}

Values presented are mean ± standard deviation of triplicate experiments. Means within a column with different superscripts are significantly different (P <0.05).WF, wheat flour; SWF1, 20% sorghum flour +80% wheat flour and SWF2,40% sorghum flour+ 60%wheat flour.

when exposed to both excess water and high temperatures (Cornejo-Ramrez *et al.*, 2018). It is an important characteristic of baking flour which is majorly governed by starch components in flour. Amylopectin is the component of flour that undergoes swelling activity. Thus, the increase in swelling power of the composite flours suggests that sorghum-wheat flour interaction increased the number of granules with free hydroxyl groups which facilitated the creation of long-chained amylopectin molecules with high hydration ability (Duduet *al.*, 2019). The increased swelling characteristic of the composite flours will be beneficial to their viscosity development which is critical to the volume development of baked foods (Onyango, 2016). These results are contrary to the findings of Adeyeye (2016) who revealed that sorghum-wheat composite flour had lower swelling power than wheat flour.

In comparison with wheat flour, composite flours containing 20% and 40% sorghum flour substitutions had 7% and 9% higher solubilities. Moreover, sorghum flour had 39% lower solubility than wheat flour. Solubility is the index of the amylose leaching activity that occurs when flour is heated at high temperature and excess water conditions. Thus, the increase in amylose leaching activity of the composite flours suggests weak amylopectin-amylose molecular interactions within their granule structures due to increased amylopectin-amylopectin interactions (Deka & Sit, 2016). The high solubility of the composite flours may lead to an increase in amylose retrogradation activity which is not suitable for baked products but may be beneficial as gelling agents in other food systems.

Pasting characteristics of composite flour

The pasting characteristics of wheat flour and composite flours consisting of different sorghum flour substitution levels are shown in Table 2. The presence of sorghum flour in wheat flour matrix had contrasting effects on pasting temperature and all composite flours had higher pasting viscosities than wheat flour.

Pasting temperature indicates the onset temperature at which the viscosity is achieved during the heating of flour in excess water conditions(Cornejo-Ramírez *et al.*, 2018). The sorghum-wheat composite flours exhibited contrasting pasting temperatures when compared with wheat flour. Composite flour with a 20% sorghum flour substation level had 1% higher pasting temperature than wheat flour. This implies that the composite flours had increased resistance potential against swelling which led to an increase in temperature requirement for viscosity development (Imoisi *et al.*, 2020). However, composite flour with 40% sorghum flour substitution level had 22% lower pasting temperature than wheat flour. The decline in pasting temperature signifies a decrease in thermal stability and energy requirement during the cooking of the composite flour (Chikpah *et al.*, 2020).

Peak viscosity is the maximum viscosity attained by flour during heating under constant shearing and excess water conditions (Alcázar-Alay & Meireles, 2015). In comparison with wheat flour, composite flour consisting of 20% and 40% sorghum flour substitution levels had 52% and 37% higher peak viscosities than wheat flour. This coincides with the swelling power results. The high peak viscosity of the composite flours signifies increased swelling ability which will be advantageous in enhancing the expansion performance of baked food systems (Adepehin, 2020; Imoisi *et al*., 2020; Mtelisi Dube *et al*., 2020).

Breakdown viscosity is an index of the structural thermo-mechanical stability of flour paste under constant shearing and excess water conditions(Dudu *et al*., 2019). It is the difference between peak viscosity and holding viscosity. Compared with wheat flour, composite flour consisting of 20% and 40% sorghum flour substitution levels had 322% and 244% higher breakdown viscosity. This implies that the dilution of wheat flour matrix by sorghum flour weakened the thermo-mechanical resistance of the paste to withstand the shear and heat conditions. Amylose can influence the structural stability of pastes during the pasting process. Dudu*et al*. (2019) attributed high breakdown viscosity of flour to high amylose leaching activity during the heating process which results in the increased amount of amylose molecules in the continuous phase of the paste thus making it incapable of withstanding thermo-mechanical conditions. This concurs with the high amylose leaching activity (high solubility) exhibited by the composite flours.

Setback viscosity predicts the amylose retrogradation ability of flour paste upon cooling (Marcel *et al*., 2020). It is the difference between final viscosity and holding viscosity. Compared with wheat flour, composite flour consisting of 20% and 40% sorghum flour substitution levels had 107% and 99% higher setback viscosity than wheat flour. This coincides with the solubility results. High setback viscosity suggests an increased tendency for amylose to reassociate with amylopectin molecules during cooling of paste or gel formation (Marcel *et al*., 2020). This characteristic may pose negative quality effects such as syneresis and staling of the baked product (Fadda *et al*., 2014; Mtelisi *et al*., 2020).

Proximate composition of composite flour and cookies

The proximate compositions of wheat flour and composite flours consisting of different sorghum substitution levels are shown in Table 3. The composite flours revealed contrasting proximate compositions when compared with wheat flour. Compared with wheat flour, composite flour consisting of 20% and 40% sorghum flour substitution levels had 0.19% and 0.34% higher ash,≈ 0.22% and 1% higher crude fibre, ≈ 3% and 4% higher carbohydrates,≈ 8% lower dry matter and lower protein and fat compositions. This was due to the higher ash, crude and carbohydrates, and lower dry matter, crude protein and fat compositions of sorghum flour when compared with wheat flour. These findings were in agreement with existing studies (Banu & Aprodu, 2020; Mtelisi *et al*., 2020) except they reported that sorghum flour had higher fat content than wheat flour. However, Adeyeye (2016) reported that sorghum flour had higher protein and lower carbohydrate content than wheat flour.

The proximate compositions of cookies from wheat flour and composite flours consisting of the different sorghum substitution levels are shown in Table 3. The effect of sorghum flour substitution on the proximate composition of the composite cookies revealed some contrasting outcomes from those of the composite flour results, indicating that interaction between sorghum flour and other additives during the baking process might have played a role. Composite flour cookies from 20% and 40% substituted sorghum flour had higher protein and had insignificantly different dry matter, ash and crude fibre compositions when compared with wheat flour cookie. Notable effects were revealed by 20% substituted sorghum flour cookie which had ≈1% higher protein and ≈ 2% higher carbohydrate compositions, as well as 40% substituted sorghum flour cookie which had ≈ 3% higher fat composition than wheat flour cookie. These results indicate the sorghum flour substitution for wheat can have positive effects on the nutritional quality of cookies which concurs with the findings of existing studies (Adeyeye, 2016; Esan *et al*., 2017)

Sensory evaluation of composite flour and cookies

The sensory characteristics of cookies from wheat flour and composite flours consisting of the different sorghum substitution levels are shown in Table 4. It was noted that consumers were unable to distinguish between cookies from wheat flour and those from composite flour. The cookie produced from 20% substituted sorghum flour had the highest overall acceptability which was determined by colour, appearance and taste. These results indicate that sorghum-wheat composite flours can effectively produce consumer acceptable cookies comparable with that from wheat flour. Adeyeye (2016) reported that consumers preferred wheat flour cookies more than those from sorghum-wheat composite flours containing 10 % to 50% sorghum flour. The author also revealed that cookies produced from 40% substituted sorghum flour had the lowest overall consumer acceptability.

Conclusion

This study established that blending sorghum flour with wheat flour had positive effects on the proximate composition, structural compactness and swelling characteristics of the composite flours. However, paste structures of the composite flours exhibited increased amylose retrogradation tendency which may lead to a decrease in shelf-life stability of the baked product. Furthermore, substituting sorghum flour for wheat flour up to 20% substitution level was capable of increasing protein content and consumer acceptability of sorghum-wheat flour cookie. It was also deduced that colour, appearance and taste are important sensory characteristics that affect consumer acceptability of cookies.

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