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Assessment of quality and sensory properties of sorghum–wheat flour cookies

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Abstract: The study was undertaken to assess the quality and sensory properties of sorghum (*Sorghum vulgare*)–wheat (*Triticum aestivum*) flour cookies. The chemical, physico-chemical parameters and sensory qualities of flours/cookies were studied and compared with control cookies from wheat flour. Sorghum flour was produced from whole sorghum grains and then incorporated at 5–50% level in wheat flour. The results revealed that substitution of wheat flour with sorghum flour significantly ($p < 0.05$) increased the moisture, ash, crude fiber, protein and fat contents of the mixture increased as the percentage of substitution of sorghum flour increased. While the sugar and starch contents decreased as the sorghum flour substitution increased. The proximate composition (moisture, ash, crude fiber, fat, protein, starch and sugar) of wheat flour were 8.64 ± 0.18, 1.57 ± 0.04, 1.42 ± 0.05, 2.29 ± 0.06, 8.48 ± 0.12, 76.92 ± 0.31 and 1.68 ± 0.13 while that of sorghum flour were 10.28 ± 0.39, 2.41 ± 0.49, 2.32 ± 0.14, 3.83 ± 0.21, 10.72 ± 0.24, 70.38 ± 0.10 and 1.16 ± 0.02. The proximate composition of composite flours with different levels of sorghum flour substitution ranged from 8.76 ± 0.19 to 9.16 ± 0.31, 1.61 ± 0.05 to 1.88 ± 0.16, 1.48 ± 0.03 to 1.79 ± 0.10, 2.36 ± 0.07 to 2.74 ± 0.12, 8.54 ± 0.12 to 9.26 ± 0.24, 75.67 ± 0.30 to 72.94 ± 0.14 and 1.63 ± 0.11 to 1.32 ± 0.05. The calorific value of the cookies decreased from 489 ± 1.88 to 421 ± 1.48 cal/100 g as the

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PUBLIC INTEREST STATEMENT

Fast and confectionery food products have become so popular in Nigeria and many other nations of the world. Wheat, the major raw material for baking has become financial burden to many tropical and developing nations as a result of the cost of importing it. Research into substitution of wheat with locally available raw materials will help in reducing the burden of wheat importation. This research work is of interest to policy makers, regulatory agents, government officials, non-governmental organizations, food processors, food vendors and the public.

percentage of sorghum flour increased in the wheat flour cookies. Sensory evaluation results showed that the color, texture, taste and overall acceptability changed significantly ($p \leq 0.05$) with increase in sorghum flour substitution. The study concluded that cookies from sorghum–wheat flour blends are advantageous as a means of reducing heavy demands on importation of wheat by developing countries.

Subjects: Environment & Agriculture; Bioscience; Food Science & Technology

Keywords: wheat; sorghum; quality; sensory; cookies

1. Introduction

Sorghum is a genus of plants in the grass family. Seventeen of the twenty-five species are native to Australia, with some extending to Africa, Asia, Mesoamerica, and certain islands in the Indian and Pacific Oceans (Mutegi et al., 2010). *Sorghum bicolor*, native to Africa with many cultivated forms now, is an important crop worldwide, used for food (as grain and in sorghum syrup or "sorghum molasses"), animal fodder, the production of alcoholic beverages, and biofuels. Most varieties are drought- and heat-tolerant, and are especially important in arid regions, where the grain is one of the staples for poor and rural people. These varieties form important components of pastures in many tropical regions. *S. bicolor* is an important food crop in Africa, Central America, and South Asia, and is the "fifth-most important cereal crop grown in the world" according to the U.S. Grains Council (Mutegi et al., 2010).

Sorghum flour is a powerhouse of nutrition and adds a superb flavor to gluten-free baking. It is high in protein, iron, and dietary fiber, making sorghum flour welcome in pantries around the world. Sorghum flour is high in antioxidants, which support cardiac health. In addition, the starch and protein in sorghum take longer than other similar products to digest. This slow digestion is particularly helpful for those with diabetes.

In a 100 g amount, raw sorghum provides 329 calories of energy, 72% carbohydrates, 4% fat and 11% protein (Mutegi et al., 2010). Sorghum supplies numerous essential nutrients in rich content (20% or more of the Daily Value, DV), including protein, the B vitamins, niacin, thiamin and vitamin B6, and several dietary minerals, including iron (26% DV) and manganese (76% DV) (Mutegi et al., 2010). Sorghum nutrient contents generally are similar to those of raw oats (Mutegi et al., 2010).

Traditionally this flour has been used as a cereal food to create pancakes, porridges, beer and flatbreads throughout different cultures, such as jowar roti in India. In the United States it is becoming more common to use sorghum flour in baked goods. It can be added or substituted in any recipe that calls for flour like cakes, cookies, breads and muffins. While some gluten free flours, such as rice flour, can add a gritty texture to cookies or bread, sorghum flour has a smoother texture that many people prefer. Due to its very mild taste, sorghum flour is a great choice to incorporate into sweet breads, cookies, or the like. Add 15–20% sorghum flour to your flour mixes to make delicious breads, cakes, and cookies.

Wheat (*Triticum* spp.) is a cereal grain, (botanically, a type of fruit called a caryopsis) (Belderok, Mesdag, & Donner 2000; Curtis, Rajaraman, & MacPherson 2002; Shewry 2009), originally from the Levant region of the Near East but now cultivated worldwide. In 2013, world production of wheat was 713 million tons, making it the third most-produced cereal after maize (1,016 million tons) and rice (745 million tons) (Belderok et al., 2000; Curtis et al., 2002; Shewry, 2009).

During recent years there has been a slow and steady increase in consumer interest for wheat (*Triticum aestivum*) free foods to minimize the risk of relatively unfamiliar condition known as celiac disease (CD) (Lovis, 2003). The celiac disease in susceptible people is gluten induced/sensitive entropy characterized by damage of small intestinal mucosa caused by gliadin fraction of wheat (Farrell & Kelly, 2002; Fasano & Catassi, 2001). These researchers suggested that the celiac disease can be treated by avoiding of gluten ingestion. Presently persons with celiac disease are unable to consume some of the most commonly available products of the market including breads, baked goods, and other food products made with wheat flour (Lovis, 2003).

During January 2007, the FDA proposed the rule for labeling gluten free products to satisfy the demand for high quality gluten free cookies/breads having similar quality of wheat flour based cookies and breads.

The objectives of this study were to prepare cookies from different formulations of composite flour and to determine chemical, physico-chemical, functional and sensory properties of cookies produced from different formulations of the composite flour.

2. Materials and methods

The wheat (*Triticum aestivum*) flour and sorghum (*Sorghum vulgare*) grains were obtained from Bodija market in Ibadan, Oyo State, Nigeria. The wheat flour was the brand of Nigerian Flour Mill while sorghum grains were sorted manually and milled using the commercial disc attrition mill. Sorghum flour was sieved by using mesh size of 250 μm opening. Other Materials/ingredients such as sugar, fat common salt and sodium bicarbonate used in this study were also bought at Bodija market. All chemicals and reagents used were of food and analytical grade.

2.1. Preparation of sorghum flour

The sorghum flour was prepared by the method reported by Houssou and Ayemor (2002). Sorghum grains were sorted and thoroughly cleaned. The sorted and cleaned whole sorghum grains were milled in a disc attrition mill locally made and allowed to pass through 250 m opening. The flour was packaged in cellophane bag until used.

2.2. Preparation of cookies

Cookies were prepared by the method reported by Abayomi, Oresanya, Opeifa, and Rasheed (2013) and Olapade and Ogunade (2014), with modification. Cookies dough prepared from wheat flour (control) and composite flours combinations using flour (100%), sugar (38%), shortening (50%), salt (0.9%), sodium bicarbonate (0.1%). Flour (500 g) from each sample of different flour blends was used for the experiment. Sugar (200 g) was creamed with margarine (250 g) until a light and fluffy constituency was obtained using Kenwood chef with initial minimum speed and the speed increased step wise until the mark of 6 on the chef indicator was attained. Whole egg (150 g) was added, followed by flour (500 g), powdered milk (50 g), baking powder (0.25 g), and salt (2.5 g) were added and mixed until a stiff paste (batter) was obtained. The batter was rolled on a floured board using rolling pin to a thickness of 0.2–0.3 cm. The rolled batter was cut into circular shapes with a cutter and arranged on a greased tray and baked at 150°C for 20 min. The cookies were brought out, cooled, and packaged in cellophane bag until used for laboratory analysis.

2.3. Proximate composition

The proximate composition of all the samples was carried out in triplicates according to the standard method Association of Official Analytical Chemists (1990).

2.4. Physico-chemical analysis of samples

The bulk density of the flour samples was determined by method of Beuchat (1977) and Olapade and Ogunade (2014). Water binding capacity was determined by method described by Beuchat (1977) and Olapade and Ogunade (2014). Dispersability of flour samples was determined by the method described by Padmashree, Vijayalakshmi, and Puttaraj (1987) was used. The swelling power of starches of the sweet potato flour, maize flour, and their blends was determined by the method described by Beuchat (1977). Particle size distribution of the flour samples was determined by the method reported by Okaka and Isieh (1990). Cookie flow was determined by method described by Okaka and Isieh (1990). Starch was described by the method descended by Hassid and Newfield

(1964). Sugar content was determined by refractometry method with the ABBE 60 Refractometer (Bellingham-Stanley Limited, Kent, England) (Van Hal, 2000). Calorific values of the cookie samples were determined by using Gallenkamp Ballistic Bomb Calorimeter (Coded CBB 330).

2.5. Physical properties of cookies

Cookies were weighed and measured for their width, thickness, spread ratio and peak force. Average values obtained for the cookies were recorded.

2.6. Sensory evaluation

Cookies prepared from wheat flour (control = R) and wheat flour with various level of sorghum flour substitution were compared and 2 = Extremely inferior to R. Two different 10-members (five men and five women), consumer-type, untrained sensory panelists were selected from undergraduate students of University of Agriculture, Abeokuta who were familiar with cookie.

2.7. Statistical analysis

All data analyzes were done in triplicates The data obtained were subjected to statistical analysis using IBM SPSS version 210 software One-way ANOVA was done on color, texture, taste, appearance, crispiness and overall acceptability using Duncan's multiple range test ($p \leq 0.05$) to study the difference between means.

3. Results and discussion

3.1. Proximate composition of the raw materials

The proximate composition of the raw materials, wheat flour, sorghum flour and composite flour are summarized in Table 1. The proximate composition (moisture, ash, crude fiber, fat, protein, starch and sugar) of wheat flour were 8.64 ± 0.18, 1.57 ± 0.04, 1.42 ± 0.05, 2.29 ± 0.06, 8.48 ± 0.12, 76.92 ± 0.31 and 1.68 ± 0.13 while that of sorghum flour were 10.28 ± 0.39, 2.41 ± 0.49, 2.32 ± 0.14, 3.83 ± 0.21, 10.72 ± 0.24, 70.38 ± 0.10 and 1.16 ± 0.02. The proximate composition of composite flours with different levels of sorghum flour substitution ranged from 8.76 ± 0.19 to 9.16 ± 0.31, 1.61 ± 0.05 to 1.88 ± 0.16, 1.48 ± 0.03 to 1.79 ± 0.10, 2.36 ± 0.07 to 2.74 ± 0.12, 8.54 ± 0.12 to 9.26 ± 0.24, 75.67 ± 0.30 to 72.94 ± 0.14 and 1.63 ± 0.11 to 1.32 ± 0.05. The moisture content of WF/SF and SF was lesser as compared to the WF. The protein content of WF/SF and SF was lower while the total carbohydrates were more as compared to WF. These results are in accordance with those reported by Mir, Gul, and Riar (2015a) for WF/SFs. The values of moisture and protein contents agreed

Table 1. The proximate compositions of wheat flour, sorghum flour and composite flour at different sorghum flour blends

Ratio of wheat flour:sorghum flour	Moisture (%)	Ash (%)	Crude fiber (%)	Fat (%)	Crude protein (%)	Starch (%)	Sugar (%)
WF (100%)	8.64 ± 0.18	1.57 ± 0.04	1.42 ± 0.05	2.29 ± 0.06	8.48 ± 0.12	76.92 ± 0.31	1.68 ± 0.13
SF (100%)	10.28 ± 0.39	2.41 ± 0.19	2.32 ± 0.14	3.83 ± 0.21	10.72 ± 0.24	70.38 ± 0.10	1.16 ± 0.02
90:10 WF/SF	8.76 ± 0.19^{a}	1.61 ± 0.05^{a}	1.48 ± 0.03^{a}	2.36 ± 0.07^{a}	8.54 ± 0.12^{a}	75.67 ± 0.30^{b}	1.63 ± 0.11^{b}
85:15 WF/SF	8.85 ± 0.20^{a}	1.68 ± 0.08^{ab}	1.56 ± 0.04^{ab}	2.47 ± 0.08^{a}	8.78 ± 0.14^{a}	75.13 ± 0.26^{b}	1.52 ± 0.10^{b}
80:20 WF/SF	8.88 ± 0.20^{a}	1.70 ± 0.08^{ab}	1.60 ± 0.05^{ab}	2.52 ± 0.09^{ab}	8.83 ± 0.15^{a}	74.96 ± 0.24^{ab}	1.49 ± 0.10^{ab}
75:25 WF/SF	8.93 ± 0.21^{a}	1.71 ± 0.08^{ab}	1.63 ± 0.05^{ab}	2.58 ± 0.10^{ab}	8.89 ± 0.16^{ab}	74.75 ± 0.23^{ab}	1.47 ± 0.09^{ab}
70:30 WF/SF	9.00 ± 0.24^{ab}	1.74 ± 0.10^{ab}	1.65 ± 0.06^{ab}	2.60 ± 0.10^{ab}	8.92 ± 0.16^{ab}	74.43 ± 0.23^{ab}	1.44 ± 0.09^{ab}
65:35 WF/SF	9.04 ± 0.26^{ab}	1.79 ± 0.12^{b}	1.69 ± 0.07^{ab}	2.63 ± 0.11^{ab}	8.97 ± 0.18^{ab}	74.16 ± 0.21^{ab}	1.40 ± 0.09^{ab}
60:40 WF/SF	9.07 ± 0.27^{ab}	1.83 ± 0.14^{b}	1.72 ± 0.08^{b}	2.66 ± 0.12^{ab}	9.11 ± 0.20^{ab}	73.87 ± 0.18^{ab}	1.38 ± 0.07^{a}
55:45 WF/SF	9.11 ± 0.28^{ab}	1.86 ± 0.15^{b}	1.74 ± 0.08^{b}	2.70 ± 0.12^{ab}	9.18 ± 0.20^{ab}	73.42±0.16^{ab}	1.35 ± 0.07^{a}
50:50 WF/SF	9.16 ± 0.31^{b}	1.88 ± 0.16^{b}	1.79±0.10^{b}	2.74 ± 0.12^{ab}	9.26 ± 0.21^{b}	72.94 ± 0.14^{a}	1.32 ± 0.05^{a}

Key: WF = wheat flour; SF = sorghum flour.

Notes: All data are means of triplicate results expressed on dry weight basis; means with the same superscripts are not significantly difference at $p \leq 0.05$; 95:5 = wheat flour:sorghum flour ratio.

with 9.6–13.5% and 9.6–10.7% reported by Abayomi et al. (2013) and Onabanjo and Ighere (2014) respectively. The values of fat and crude fiber contents of the wheat and sorghum flour agreed with the findings of Oboh, Ologhobo, and Tewe (1989), Adedeji, Oyinloye, and Ocheme (2014), Abayomi et al. (2013) and Onabanjo and Ighere (2014). The higher values of fat and fiber in the sorghum flour may be due to the fact that sorghum was not de-germed and dehulled before milling. The starch contents of the wheat flour and sorghum flour agreed with values reported by Purseglove (1985) and Oboh (1986). The values of sugar contents reported above for wheat flour and sorghum flour, respectively agreed with 2.0 and 3.7–10.4% reported by Purseglove (1985), Oboh et al. (1989), Adedeji et al. (2014), Abayomi et al. (2013) and Onabanjo and Ighere (2014).

The moisture, ash, crude fiber, fat, protein, starch and sugar contents of wheat flour, sorghum flour and flour substituted with 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50%, respectively, sorghum flour were significantly different ($p \leq 0.05$). The moisture, ash, crude fiber, protein and fat contents of the mixture increased as the percentage substitution of sorghum flour increased. While the sugar and starch contents decreased as the sorghum flour substitution increased.

3.2. Physico-chemical properties of wheat flour, sorghum flour and composite flour at different sorghum flour blends

The physico-chemical properties of the flour samples are presented in Table 2. The bulk density of wheat flour (control) was highest (5.82 ± 1.91 g/ml) while that of the sorghum flour was lowest (3.27 ± 0.96 g/ml). The bulk density of wheat flour decreased with increasing substitution of sorghum flour. The water-binding capacity of the wheat flour (control) was 1.89 ± 0.22 g/ml and higher than 0.62 ml/g reported by Adeyemi and Idowu (1990), and this may be due to different methods applied for the water binding capacity. The water binding capacity of composite flour decreased as the level of sorghum flour substitution increased. Because WBC of wheat flour was highest of all, these eventually less in substituted flours. Flour dispersibility gives an indication of particles suspensibility in water, which is useful functional parameter in various food products formulations (Mora-Escobedo, Lopez, & Lopez, 1991). The dispersability of the flour was 23.52 ± 2.33% for 100% sorghum flour. Greater dispersability indicates greater reconstitution ability of the flour (Abayomi et al., 2013; Adeyemi & Idowu, 1990; Olapade & Ogunade, 2014).

Table 2. Physico-chemical properties of wheat flour, sorghum flour and composite flour at different sorghum flour blends

Ratio of wheat flour:sorghum flour	Bulk density	Dispersability	Water binding capacity	Swelling power at 95°C
WF (100%)	5.82 ± 1.91^{c}	53.41 ± 3.89^{d}	1.89 ± 0.22^{b}	15.06 ± 1.89^{f}
SF (100%)	3.27 ± 0.96^{a}	23.52 ± 2.33^{a}	1.03 ± 0.10^{a}	8.59 ± 0.93^{a}
90:10 WF/SF	5.63 ± 1.85^{c}	51.38 ± 3.76^{d}	1.83 ± 0.21^{b}	14.28 ± 1.74^{e}
85:15 WF/SF	4.96 ± 1.69^{bc}	45.93 ± 3.45^{c}	1.72 ± 0.19^{b}	12.49 ± 1.51^{d}
80:20 WF/SF	4.72 ± 1.57^{bc}	42.68 ± 3.37^{c}	1.66 ± 0.18^{ab}	12.18 ± 1.47^{d}
75:25 WF/SF	4.58 ± 1.46^{b}	40.71±3.28^{c}	1.61 ± 0.17^{ab}	11.73 ± 1.42^{c}
70:30 WF/SF	4.34 ± 1.38^{b}	38.19 ± 3.12^{b}	1.55 ± 0.16^{a}	11.41 ± 1.39^{c}
65:35 WF/SF	4.25 ± 1.33^{b}	35.16 ± 2.91^{b}	1.49 ± 0.14^{a}	10.82 ± 1.34^{b}
60:40 WF/SF	4.13 ± 1.30^{b}	32.19 ± 2.83^{b}	1.42 ± 0.14^{a}	10.59 ± 1.28^{b}
55:45 WF/SF	3.91 ± 1.27^{ab}	28.11 ± 2.71^{a}	1.34 ± 0.13^{a}	9.74 ± 1.21^{ab}
50:50 WF/SF	3.80 ± 1.23^{ab}	27.28 ± 2.59^{a}	1.26 ± 0.12^{a}	9.53 ± 1.18^{ab}

Key: WF = wheat flour SF = sorghum flour.

Notes: All data are means of triplicate results expressed on dry weight basis; means with the same superscripts are not significantly difference at $p \leq 0.05$; 95:5 = wheat flour:sorghum flour ratio.

Dispersability of wheat flour decreased as more sorghum flour was being added to composite flour. The high dispersability of wheat flour when compared with that of sorghum flour or composite flour might be due to the nature of the wheat and sorghum flour starch. The higher is the dispersibility, the better is the flour's ability to reconstitute in water to have a fine and consistent paste and gives an indication of good water absorption capacity (Kulkarni, Kulkarni, & Ingle, 1991).

Wheat flour has highest swelling power followed by the composite flour and sorghum flour has the least. Substitution of wheat flour with sorghum flour reduced the swelling power of the flour (Akpapunam & Darbe, 1994). This might be due to might be due to reduction in gluten content of wheat flour, that is, dilution effect.

3.3. Proximate composition of cookies from wheat flour and composite flour at different sorghum flour blends

The results of proximate composition of cookies from wheat flour and composite flour at different sorghum flour blends are shown in Table 3. The moisture content of cookies from wheat flour (control) was 6.87 ± 0.19 while that of sorghum flour was 5.08 ± 0.10. The moisture content of cookies from composite flour ranged between 6.18 ± 0.18 and 5.16 ± 0.10 for 5 and 50% sorghum flour respectively (Table 3). The ash, crude fiber, fat, protein and sugar contents of cookies from wheat flour (control) were 4.95 ± 0.07, 3.31 ± 0.08, 9.93 ± 0.08, 6.78 ± 0.10 and 4.62 ± 0.14 while that of sorghum flour were 5.98 ± 0.10, 4.02 ± 0.16, 8.53 ± 0.01, 8.91 ± 0.28 and 3.18 ± 0.04. The ash, crude fiber, fat, protein and sugar contents of cookies from composite flour ranged between 4.98 ± 0.07 and 3.78 ± 0.12, 3.42 ± 0.08 and 3.91 ± 0.14, 9.76 ± 0.07 and 8.71 ± 0.02, 6.91 ± 0.12 and 8.72 ± 0.24 and 4.58 ± 0.14 and 3.32 ± 0.07 for 5% and 50% sorghum flour respectively. The result of the moisture and fat contents agreed with the report of Semwat, Narsimhamurty, and Arya (1996) who reported moisture content (2.47–8.75%) and fat content (1.04–14.82%) in different commercially available biscuits. Rajput, Rao, and Shurpalekar (1988) also reported that biscuits containing unconventional protein sources increased the protein content in biscuits from 5.9 to 11.5–18.1% which also agreed with outcome of this research.

Table 3. The proximate compositions of cookies from wheat flour and composite flour at different sorghum flour blends

Ratio of wheat flour:sorghum flour	Moisture (%)	Ash (%)	Crude fiber (%)	Fat (%)	Crude protein (%)	Sugar (%)
WF (100%)	6.87 ± 0.19^{b}	4.92 ± 0.07^{a}	3.31 ± 0.08^{a}	9.93 ± 0.08^{b}	6.78 ± 0.10^{a}	4.62 ± 0.14^{b}
SF (100%)	5.08 ± 0.10^{a}	5.98 ± 0.14^{b}	4.02 ± 0.16^{c}	8.53 ± 0.01^{a}	8.91 ± 0.28^{c}	3.18 ± 0.04^{a}
90:10 WF/SF	6.18 ± 0.18^{b}	4.98 ± 0.07^{a}	3.42 ± 0.08^{a}	9.76 ± 0.07^{b}	6.91 ± 0.12^{a}	4.58 ± 0.14^{b}
85:15 WF/SF	5.72 ± 0.15^{ab}	5.25 ± 0.08^{a}	3.53 ± 0.09^{a}	9.53 ± 0.06^{ab}	7.32 ± 0.15^{b}	4.18 ± 0.12^{ab}
80:20 WF/SF	5.59 ± 0.15^{ab}	5.32 ± 0.09^{a}	3.62 ± 0.10^{ab}	9.45 ± 0.06^{ab}	7.69 ± 0.17^{b}	3.93 ± 0.11^{ab}
75:25 WF/SF	5.43 ± 0.14^{b}	5.39 ± 0.09^{b}	3.70 ± 0.10^{ab}	9.39 ± 0.05^{ab}	7.87 ± 0.18^{b}	3.84 ± 0.11^{ab}
70:30 WF/SF	5.38 ± 0.14^{a}	5.46 ± 0.10^{ab}	3.74 ± 0.11^{ab}	9.28 ± 0.05^{ab}	8.01 ± 0.19^{c}	3.71 ± 0.10^{a}
65:35 WF/SF	5.31 ± 0.12^{a}	5.53 ± 0.10^{ab}	3.78 ± 0.11^{ab}	9.11 ± 0.04^{ab}	8.23 ± 0.20^{c}	3.64 ± 0.10^{a}
60:40 WF/SF	5.27 ± 0.12^{a}	5.61 ± 0.11^{ab}	3.81 ± 0.12^{ab}	8.92 ± 0.04^{a}	8.40 ± 0.21^{c}	3.50 ± 0.09^{a}
55:45 WF/SF	5.23 ± 0.11^{a}	5.70 ± 0.12^{ab}	3.86 ± 0.13^{ab}	8.80 ± 0.03^{a}	8.61 ± 0.22^{c}	3.44 ± 0.08^{a}
50:50 WF/SF	5.16 ± 0.10^{a}	5.78 ± 0.12^{ab}	3.91 ± 0.14^{ab}	8.71 ± 0.02^{a}	8.72 ± 0.24^{c}	3.32 ± 0.07^{a}

Key: WF = wheat flour SF = sorghum flour.

Notes: All data are means of triplicate results expressed on dry weight basis; means with the same superscripts are not significantly difference at $p \leq 0.05$; 95:5 = wheat flour:sorghum flour ratio.

3.4. Physical properties of cookies

The results of the physical properties of the cookies are shown in Table 4. Spread ratio or diameter of cookies has long been used to determine the quality of flour for producing cookies (Gaines, 1994). Cookies prepared from wheat flour had more spread ratio as compared to WF/SF and SF cookies which decreased with the substitution of more sorghum flours. This might be due to nature of starch present in wheat and sorghum flours (Gul, Riar, Bala, & Sibian, 2014; Mir, Gul, & Riar, 2015b). The weight, diameter and the spread ratio of the cookies followed the same trend in which an increase in sorghum flour increases the physical parameters. The weight of cookies from wheat flour and sorghum flour were 58.91 ± 0.83 and 40.38 ± 0.12. The width, height, spread ratio and thickness of cookies from wheat flour and sorghum flour ranged between 4.53 ± 0.36–3.19 ± 0.13, 0.38 ± 0.19–0.20 ± 0.03, 5.5 ± 0.64–3.0 ± 0.26 and 0.93 ± 0.18–0.68 ± 0.10 and 4.46 ± 0.28–3.41 ± 0.14, 0.34 ± 0.18–0.20 ± 0.03, 5.0 ± 0.61–3.0 ± 0.26 and 50.91 ± 0.16–0.71 ± 0.10. The high dietary fiber content of whole sorghum flour might be attributed for the low weight observed in cookies made from whole sorghum flour and sorghum flour substituted wheat flour. The spread ratio ranged from 3.0 to 5.0. Spread ratio increases with a reduction in sorghum flour in the cookies, this agreed with the work of Ayo and Gaffa (2002). High spread ratio of wheat flour cookies might be due to high gluten content of wheat flour. There were significant differences ($p \leq 0.05$) between the weight, thickness, width and spread ratio of 100% wheat flour biscuit (control) compared to that of sorghum–wheat composite flour cookies. This result is contrary to the findings of Adebowale, Adegoke, Sanni, Adegunwa, & Fetuga (2012) who reported no significant difference in the thickness and spread ratio of wheat and sorghum composite biscuit with increased proportion of sorghum flour. But agreed with Mridula, Gupta, and Manikantan (2007), who reported significant reduction in the thickness and spread ratio of wheat-soybean and sorghum composite biscuit with increased proportion of sorghum flour.

3.5. Calorific values, cookie flow and break strength properties from wheat flour and composite flour at different sorghum flour blends

The results of calorific values of samples from wheat flour, sorghum flour substituted wheat flour cookies are presented in Table 5. Cookies made from wheat flour (control) had the highest energy (489 ± 1.88 cal/100 g). This value agreed with the value of 493 cal/100 g reported by McCance and Widdowson (1991) for digestive biscuits. The calorific value of sorghum composite flour cookies decreased with increasing concentration of sorghum flour substitution. The greater energy of the wheat flour cookies over that of composite flour cookies may be due to decline in fat and sugar contents (Table 4). The calorific values of the cookies from sorghum–wheat flour showed that they

Table 4. The physical characteristics of cookies from wheat flour and composite flour at different sorghum flour blends

Ratio of wheat flour:sorghum flour	Weight (g)	Width (W) (cm)	Height (H) (cm)	Spread ratio (W/T)	Thickness (T)
WF (100%)	58.91 ± 0.83^{c}	4.53 ± 0.36^{c}	0.38 ± 0.19^{b}	5.5 ± 0.64^{d}	0.93 ± 0.18^{d}
SF (100%)	40.38 ± 0.12^{a}	3.19 ± 0.13^{a}	0.20 ± 0.03^{a}	3.0 ± 0.26^{a}	0.68 ± 0.10^{a}
90:10 WF/SF	53.67 ± 0.73^{c}	4.46 ± 0.28^{b}	0.34 ± 0.18^{b}	5.0 ± 0.61^{d}	0.91 ± 0.16^{d}
85:15 WF/SF	50.44 ± 0.68^{c}	4.09 ± 0.26^{b}	0.31 ± 0.16^{b}	4.6 ± 0.53^{c}	0.89 ± 0.14^{c}
80:20 WF/SF	49.89 ± 0.52^{b}	3.92 ± 0.17^{ab}	0.29 ± 0.08^{a}	4.2 ± 0.49^{c}	0.87 ± 0.14^{c}
75:25 WF/SF	47.93 ± 0.49^{b}	3.84 ± 0.29^{ab}	0.26 ± 0.14^{a}	3.9 ± 0.42^{b}	0.86 ± 0.13^{c}
70:30 WF/SF	46.21 ± 0.43^{b}	3.71 ± 0.18^{ab}	0.24 ± 0.13^{a}	3.6 ± 0.40^{b}	0.84 ± 0.11^{c}
65:35 WF/SF	45.66 ± 0.36^{b}	3.70 ± 0.16^{ab}	0.23 ± 0.09^{a}	3.4 ± 0.37^{a}	0.81 ± 0.11^{c}
60:40 WF/SF	44.38 ± 0.28^{a}	3.62 ± 0.15^{ab}	0.22 ± 0.07^{a}	3.2 ± 0.34^{a}	0.76 ± 0.10^{b}
55:45 WF/SF	43.82 ± 0.27^{a}	3.54 ± 0.23^{ab}	0.20 ± 0.05^{a}	3.1 ± 0.28^{a}	0.73 ± 0.10^{b}
50:50 WF/SF	42.70 ± 0.14^{a}	3.41 ± 0.14^{a}	0.20 ± 0.03^{a}	3.0 ± 0.26^{a}	0.71 ± 0.10^{b}

Key: WF = wheat flour SF = sorghum flour.

Notes: All data are means of triplicate results expressed on dry weight basis; means with the same superscripts are not significantly difference at $p \leq 0.05$; 95:5 = wheat flour:sorghum flour ratio.

Table 5. Calorific values, cookie flow and break strength properties of cookies from wheat flour and composite flour at different sorghum flour blends

Ratio of wheat flour:sorghum flour	Cookie flow (%)	Cookie break strength (kg)	Energy (Cal/100 g)
WF (100%)	64.83 ± 1.82^f	2.54 ± 0.24^c	489 ± 1.88^d
SF (100%)	28.16 ± 0.83^a	1.49 ± 0.09^a	327 ± 1.14^a
90:10 WF/SF	61.36 ± 1.78^f	2.49 ± 0.22^b	476 ± 1.82^d
85:15 WF/SF	52.81 ± 1.53^e	2.31 ± 0.20^b	467 ± 1.74^d
80:20 WF/SF	47.68 ± 1.47^d	2.26 ± 0.18^b	458 ± 1.69^d
75:25 WF/SF	42.82 ± 1.38^c	2.18 ± 0.16^b	443 ± 1.61^c
70:30 WF/SF	36.47 ± 1.24^b	2.09 ± 0.14^b	435 ± 1.57^c
65:35 WF/SF	33.54 ± 1.17^a	1.96 ± 0.12^{ab}	421 ± 1.48^c
60:40 WF/SF	32.04 ± 1.14^a	1.83 ± 0.11^{ab}	410 ± 1.39^c
55:45 WF/SF	31.15 ± 1.09^a	1.71 ± 0.11^a	396 ± 1.32^b
50:50 WF/SF	30.63 ± 1.02^a	1.64 ± 0.10^a	378 ± 1.26^b

Key: WF = wheat flour SF = sorghum flour.

Notes: All data are means of triplicate results expressed on dry weight basis; means with the same superscripts are not significantly difference at $p \leq 0.05$; 95:5 = wheat flour:sorghum flour ratio.

are comparable with similar products from wheat, barley, and sorghum (McCance & Widdowson, 1991). Cookies prepared from WF had more breaking strength than the ones prepared from wheat flour/sorghum flour blend (Table 5).

Cookie flow and break strength of cookies made from wheat flour (control), sorghum flour and composite flour were 64.83 ± 1.83 and 2.54 ± 0.24, 28.16 ± 0.82 and 1.49 ± 0.09, 61.36 ± 1.78 and 2.49 ± 0.22 and 30.63 ± 1.02 and 1.64 ± 0.10, respectively. The cookie flow and break strength decreased as the percentage of sorghum flour in the cookies increased. This might be due to decrease in the starch content of sorghum flour as whole sorghum grains were milled into flour.

3.6. Sensory evaluation of cookies

The results of the sensory evaluation are shown in Table 6. The control from wheat flour had the value of 8.02 ± 0.22 rated the highest in terms of overall acceptability while the cookies from

Table 6. Mean sensory evaluation of cookie samples from wheat flour and composite flour at different sorghum flour substitution (Hedonic scale)

Ratio of wheat flour:sorghum flour	Appearance	Color	Taste	Texture	Flavor	Crispiness	Overall acceptability
WF (100%)	8.29 ± 0.28^h	8.43 ± 0.19^g	5.28 ± 0.16^b	6.81 ± 0.18^a	7.80 ± 0.24^d	8.86 ± 0.20^e	8.02 ± 0.22^e
SF (100%)	3.84 ± 0.07^a	4.07 ± 0.08^a	4.89 ± 0.09^a	7.83 ± 0.26^e	6.05 ± 0.12^a	6.78 ± 0.08^a	6.41 ± 0.09^a
90:10 WF/SF	7.93 ± 0.26^g	6.89 ± 0.18^f	6.81 ± 0.24^d	7.65 ± 0.24^d	7.21 ± 0.22^c	8.49 ± 0.18^d	7.92 ± 0.20^d
85:15 WF/SF	6.98 ± 0.24^f	6.27 ± 0.16^e	7.90 ± 0.28^e	7.20 ± 0.22^b	6.08 ± 0.14^a	8.05 ± 0.16^d	7.58 ± 0.16^d
80:20 WF/SF	6.52 ± 0.22^e	6.08 ± 0.14^e	6.67 ± 0.24^d	7.64 ± 0.24^d	7.28 ± 0.22^c	7.59 ± 0.15^c	7.26 ± 0.15^c
75:25 WF/SF	5.86 ± 0.20^d	5.82 ± 0.13^d	5.92 ± 0.22^c	6.83 ± 0.18^a	6.73 ± 0.18^b	7.42 ± 0.14^b	6.91 ± 0.14^{ab}
70:30 WF/SF	5.43 ± 0.18^c	5.20 ± 0.12^c	5.38 ± 0.20^b	7.54 ± 0.24^c	6.26 ± 0.16^a	7.08 ± 0.13^b	6.88 ± 0.12^{ab}
65:35 WF/SF	5.12 ± 0.16^c	4.98 ± 0.11^b	5.13 ± 0.16^b	7.58 ± 0.24^c	6.25 ± 0.16^a	7.06 ± 0.13^b	6.86 ± 0.12^{ab}
60:40 WF/SF	4.71 ± 0.14^b	4.67 ± 0.10^b	5.09 ± 0.14^b	7.53 ± 0.24^c	6.26 ± 0.16^a	7.03 ± 0.12^b	6.83 ± 0.12^{ab}
55:45 WF/SF	4.16 ± 0.12^{ab}	4.42 ± 0.10^a	5.06 ± 0.13^b	7.51 ± 0.24^c	6.24 ± 0.16^a	7.01 ± 0.11^b	6.80 ± 0.12^{ab}
50:50 WF/SF	4.02 ± 0.10^{ab}	4.18 ± 0.10^a	5.00 ± 0.13^b	7.50 ± 0.24^c	6.22 ± 0.16^a	7.00 ± 0.10^b	6.69 ± 0.10^{ab}

Key: WF = wheat flour; SF = sorghum flour.

Notes: All data are means of triplicate results expressed on dry weight basis; means with the same superscripts are not significantly difference at $p \leq 0.05$; 95:5 = wheat flour:sorghum flour ratio.

sorghum flour had least overall acceptability value of 6.41 ± 0.09. The results also showed that cookies from sorghum–wheat flour had high overall acceptability but the value decreases has the percentage of substitution increases. For the organoleptic test 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50% levels of substitution were not significantly different from each other in terms of their comparison with the control from wheat flour. However, they were significantly different from and 100% wheat flour (control) except for texture and crispiness, where there was no significant difference between the mean scores of all levels of substitution. A change in color was detected at 35% level of substitution, and this became intense at 50% level. Although the product also had high overall acceptability, majority of the panelists' complaints about the color, taste and texture of the product above 35% substitution of wheat flour with sorghum flour. Cookies prepared from formulations (10% WF/SF and 15% WF/SF) were more acceptable than other formulations. Similar results were reported by Mir et al. (2015b) for cakes by increasing non-wheat flour in the formulation.

4. Conclusion

In conclusion, this study has revealed that cookies of acceptable and desirable physical properties and chemical composition comparable to 100% wheat flour cookies could be produced from sorghum–wheat composite flour. The sorghum–wheat flour cookies could therefore be of health benefits to the people and as well as a means of reducing heavy demands on importation of wheat by developing countries.

5. Practical application

The present study provides a method for producing cookies from composite flour that were comparable to wheat cookies. The wheat flour and sorghum flour and their blends in formulations were used for the preparation of cookies. The blend may reduce over-dependence of countries in sub-Sahara Africa on wheat importation.

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