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Unripe banana and defatted sesame seed flours improve nutritional profile, dietary fibre and functional properties of gluten-free sorghum cookies

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Abstract

Rising incidence of nutritional deficiency and chronic diseases among celiacs continuously drives the food industry to search for novel functional ingredients high in health-promoting constituents such as dietary fibre and protein. This study investigated the impact of unripe banana flour and sesame meal addition as functional ingredients to enhance the dietary fibre, nutritional profile and functional properties of gluten-free sorghum cookies. Gluten-free sorghum cookies were prepared using composite sorghum flours (SF) formulated by alternately replacing SF (30–65%) with unripe Cardaba banana flour (CBF) (30–65%) and sesame meal (SM) (5%). Nutritional composition, mineral molar ratios, dietary fibre and functional properties of the flours and cookies were assessed using standard methods. Physical parameters including diameter, thickness, spread ratio and weights as well as the sensory attributes of the cookies were evaluated. While sesame meal addition significantly ($p \leq 0.05$) influenced protein enhancement, CBF inclusion significantly enhanced ash, insoluble dietary fibre, mineral contents and functional properties of sorghum flours and cookies. The significantly ($p \leq 0.05$) higher values in thickness, diameter and spread ratio composite cookies containing higher CBF [CBC65 (cookie with 65% CBF) had the highest values] may indicate CBF addition enhanced the cookie-making potential of sorghum flour. Similarly, its highest flavor, aftertaste and overall acceptability scores as compared to the control (100% wheat cookie) or other composite cookies may have been influenced by the combined sweetness of banana's natural flavor and sugars produced during baking. The incorporation of Cardaba banana flour into sorghum cookie formulation may hold interesting potential as a rich source of dietary fibre and other bioactive compounds as well as aiding functional and sensory enhancement of sorghum flour. Defatted sesame seed flour when incorporated into this blend at a ratio not more than 5% may aid in the production of organoleptically acceptable enriched gluten-free sorghum:Cardaba banana:defatted sesame cookies that could offer nutritional and health benefits for both gluten-sensitive and non-gluten-sensitive consumers.

Keywords Cardaba banana, Celiac disease, Dietary fibre, Gluten-free, Cookies, Legume proteins, Resistant starch, Sorghum, Functionality

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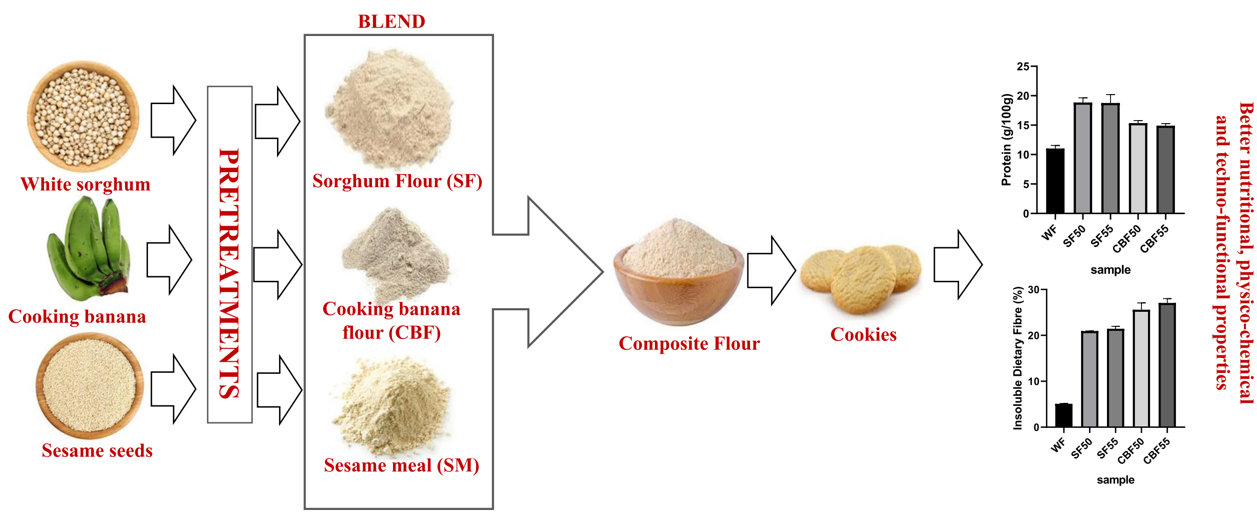
Graphical Abstract



Introduction

In the last decade, the food industry has made significant progress in the development of suitable gluten-free (GF) flours which offer similar functionality and quality that mimic the viscoelastic property of the gluten network. This has resulted in the development of a wide variety of GF foods with unique and interesting characteristics (Cappelli et al. 2020; Houben et al. 2012; Rai et al. 2018; Wang et al. 2017). However, this progress seems to have been negated by the increasing incidence of chronic diseases, oxidative stress, metabolic disorders and nutritional deficiency among celiac disease patients due to the low contents of nutritional and health-promoting constituents of GF products (Gumul et al. 2021; Maluf et al. 2020; Rowicka et al. 2018). Basically, most commercially-available GF flours are composed of starch and hydrocolloids, being characterized by high rapidly-digestible starch (RDS) and low dietary fibre (DF) which invariably elicit higher glycemic index (GI) and post-prandial glucose and insulin responses as compared to gluten-based flours. In addition, these flours are usually inferior in nutritional value (being deficient in protein and micronutrients) and health-promoting constituents such as dietary fibre, which play significant role in the prevention and management of many chronic diseases and cancers (de Gennaro et al. 2022; Gumul et al. 2021). Furthermore, the desirability of DF in the formulation of GF bakery products is linked to its high oil (OHC) and water holding capacities (WHC), fat mimetic properties and textural and thickening effects (de Gennaro et al. 2022; Hua et al. 2019; Tsatsaragkou et al. 2016). On the other hand, legume proteins enhance the amino acid balance, act as structure-forming agents and improve sensory quality of GF foods by increasing Maillard browning and flavor (Deora et al. 2015; Ziobro et al. 2016).

Growing consumer education and awareness of these concerns currently drive the demand for development of healthier new gluten-free foods containing functional ingredients with health-promoting constituents such as dietary fibre, protein and micronutrients (Belmiro et al. 2022; Galanakis 2015). However, an important requirement for the sustainability of these diets is that the raw materials must be locally available, readily obtainable in large quantities and at affordable costs. Plant-based products offer more promising potentials as functional ingredients due to their availability, sustainability and reduced negative impact on the environment, as well as their low costs. In addition, they are usually high in dietary fibre, indigestible carbohydrates and other antioxidant compounds (Belmiro et al. 2022; Galanakis 2015). Aside these issues, another important consideration is that the use of alternate flours from locally-available cereals, roots, tubers and legumes to replace wheat would significantly boost the economies of non-wheat cultivating low- and medium-income tropical developing countries by reducing dependence on imported wheat, thereby reducing debt burden accrued from its importation (Ayo-Omogie 2021; Benayad et al. 2021; Dudu et al. 2020; Kotsiou et al. 2022). Moreover, the ongoing Russia-Ukraine war which is raising global food prices, including in Nigeria that mainly imports wheat from Russia and other black sea countries, will continue to increase the debt burden. According to FAS Lagos, Nigeria's current wheat importation was estimated at 6.0 million metric tons (MMT) for the MY 2022/2023 (USDA 2022). Consequently, increase in prices of wheat-based products within the last 12 months has increased demand for substitutes and other non-wheat staples, while the country's wheat millers continue to seek alternative sources to diversify their wheat imports. As such, production of locally-available cereals such as corn, rice and sorghum is currently increasing and are being diversified as wheat althernates (USDA 2022).

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop produced globally after rice, wheat, maize and barley and the second most cultivated cereal after maize in sub-Saharan Africa (SSA) (Mabhaudhi et al. 2016; Sobowale et al. 2019). Its unique adaptability to both tropical and warm temperate conditions (FAO 2003; Ogunsakin et al. 2015) makes it a cereal that can contribute significantly to the highly-increasing gluten-free food market, not only for developing countries but also around the world. Owing to its gluten-free status, it has been widely utilized in the development of high-fibre gluten-free bakery products safe for CD patients (Onyango et al. 2011; Rai et al. 2018; Schober & Bean 2008; Taylor & Emmambux 2018). It is a rich source of calorie, variety of nutrients and beneficial food components including polyunsaturated fatty acids, dietary fibre, non-starch polysaccharides, beneficial bioactive peptides and antioxidants. Its protein (which averages 11–12%) is more closely related to maize than wheat, rye and barley (Schober & Bean 2008; Awika 2017; Pontieri & Del Giudice 2016). However, sorghum is limited in essential amino acids such as lysine, threonine and tryptophan (Adebo 2020). Previous studies have reported the fortification of sorghum with legumes such as groundnut meal and soybean in protein-enriched gluten-free cookies (Ahure & Ejoha 2020; Man et al. 2014; Omoba et al. 2015; Rai et al. 2014). However, these legumes are largely known, highly utilized at industrial scale in the manufacture of a large number of industrial products, and consequently relatively expensive. Hence, a lesser-known, under-utilized and cheap oilseed such as sesame may hold greater potential for formulation of low-cost protein-fortified GF bakery foods.

Sesame (*Sesamum indicum* Linn) is an under-utilized leguminous oilseed considered globally as a promising functional food due to its nutritional and phytochemical composition. It is a rich source of oil (44–60%), proteins (30–60%), essential amino acids, fatty acids, vitamins, minerals, bioactive components and a specific class of lignans (Demirhan & Özbek 2013; Dossou et al. 2022). Furthermore, previous studies have reported its antioxidative, anti-nitrosative, anti-obesity, heavy metal-binding and protective effects against metabolic disorders and non-alcoholic fatty liver diseases (Kim et al. 2014; Manini et al. 2016; Panzella et al. 2012; Ruslan et al. 2018; Yang et al. 2018). Earlier, Hui (1996) had reported that sesame increases plasma tocopherol and vitamin E activity known to prevent cancer and heart disease. Although in Nigeria sesame seed is the most sought-after cash crop (after cocoa) and currently the country's leading agricultural export, it is largely unknown to many citizens. This is despite being the second largest producer in the African continent (responsible for 26% of global production), seventh globally and the primary supplier to the world's largest importer, Japan (Namiki 1995; Chemonics International Inc. 2002). Few studies have reported its exploitation in food-to-food fortification of GF bakery products. Hence, the need to harness it as a cheap source of good quality protein and functional ingredient in blended cereal-legume composite gluten-free flours for bakery products.

Bananas are abundantly produced in tropical and subtropical countries of the world. Their rich contents of indigestible compounds including resistant starch and non-starch polysaccharides such as dietary fibre, high micronutrient contents and bioactive compounds including antioxidant, make them more popular globally as functional ingredients for development of a wide range of foods (Adeola & Ohizua 2018; Agama-Acevedo et al. 2012; Alcântara et al. 2020; Aparicio-Saguilán et al. 2006; Juárez-García et al. 2006; Ovando-Martinez et al. 2009). Apart from the low-postprandial response to glucose and insulin that resistant starch exerts due to its resistance to α-amylase and glucoamylase digestion in the upper gastrointestinal tract (thus preventing/controlling diabetes mellitus and obesity), it also offers protection against colorectal cancer and hypocholesterolemic action (Birt et al. 2013; Englyst & Cummings 1986; Topping & Clifton 2001). Technologically, RS plays similar gel-structure-forming, CO_2-retention properties as hydrocolloids and does not increase crumb firmness but improves elasticity and gel porosity in GF bakery products (Tsatsaragkou et al. 2014; Witczak et al. 2016). Unfortunately, bulk of bananas produced in Nigeria is often lost to postharvest deteriorative processes and up to 30–100% losses have been reported (Ayo-Omogie et al. 2010; Oluwalana et al. 2005). In particular, cooking varieties such as Cardaba (*Musa* ABB) despite being a rich source of important micronutrients with higher amounts (in comparison to plantain) of resistant starch and dietary fibre, included to its low glycemic index, and high phenolic and flavonoid contents, is grossly under-utilized (Ayo-Omogie et al. 2010, 2021; Falodun et al. 2019). Since it is readily available year round and relatively cheap, it could be converted to functional ingredient for development of novel foods such as GF cookies.

It can be hypothesized that the blending of sorghum with Cardaba banana flour and defatted sesame seed may aid in the development of nutrient-dense gluten-free cookies with enhanced nutritional profiles and dietary fibre which could have physiological benefits for consumers as compared to wheat cookies. Although several studies have reported the use of each of these flours in developing gluten-free cookies, none has combined them in a single experiment. The objective of this study was to investigate the effect of defatted sesame seed meal (SM) and Cardaba banana flour (CBF) addition on the nutritional profile, dietary fibre composition, functional properties and cookie-making potentials of sorghum flour (SF).

Materials and methods

Material acquisition and chemicals

About 10 kg each of white sorghum variety and sesame seeds were obtained from Kuje market in Abuja, Nigeria and transported to the Federal University of Technology, Akure, Ondo State, Nigeria where this study was carried out. Green mature cooking banana (*Musa* ABB cultivar Cardaba) was obtained from the Teaching and Research Farm of the University, while wheat flour (Golden Penny Plc. Lagos, Nigeria), baking powder (Opekad Industries Nig. Ltd.), sugar (Dangote Refinery Plc, Lagos, Nigeria), full cream milk powder (Arla Foods amba, iby J., Denmark), eggs, and shortening (Jubi Margarine, PT Citra Nutrindo Langgeng, JL Rungkut Industrii/21, Surabaya JI 60293, Indonesia) were purchased from the shopping mall in Akure, Ondo State, Nigeria. All reagents used were of analytical grade.

Processing of Cardaba banana and sorghum flours

Cardaba banana flour (CBF) was prepared according to the methods of Ayo-Omogie et al. (2010). Briefly, the bananas were defingered from the pseudostem, washed with clean tap water, peeled, sliced into 10 mm slices using a stainless-steel knife and soaked in 0.02% sodium metabisluphite solution for 30 min. Thereafter, sulphited slices were drained and oven-dried using a Gallenkamp hot air oven (Model 320; Gallenkamp, England) at 55° C for 24 h. Dried chips were milled using a hammer mill (Armfield), sieved through a 500- µm sieve, packaged in polyethene bags, placed in airtight containers and stored at 4 °C. Sorghum flour (SF) was produced as described by Omoba et al. (2015). Briefly, whole grains were sorted, milled into coarse whole grain flour using a laboratory hammer mill with a 500 µm opening screen. The flour was packaged and stored at 4 °C.

Processing of defatted sesame seed flour

The method of El-Adawy (1997) was adopted for preparation of defatted sesame seed flours (SM) with slight modification. The seeds were sorted to remove bad seeds and extraneous materials, soaked overnight at ambient temperature (25 ± 2° C) in clean tap water, and dehulled using flotation method by rubbing between the palms. Thereafter, the dehulled seeds were blanched using hot water for 5 min, washed in cold tap water, drained, oven-dried (Model 320, Gallenkamp, England) at 60° C, milled into flour with an attrition mill (Asiko Attrition Mill, Lagos, Nigeria; Serial No A11) and sieved using a 60 mm mesh sieve (British Standard). To extract the oil, the full-fat sesame flour was poured into a white muslin cloth, placed in a Soxhlet extractor, hexane was poured and allowed to defat for 12 h. The defatted sesame flour was desolventized by air-drying for 30 min, milled into fine powder using a laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK), packed into plastic containers with lids and stored at 4 °C in a refrigerator.

Formulation of flour blends

The experiments were based on a completely randomized block sampling method with flour blend formulations mixed to obtain eight (8) composite samples where sorghum (SF) and Cardaba banana (CBF) flours were varied alternately between 30 and 65%. Defatted sesame seed flour (SM) was kept constant at 5% following preliminary test trial experiments where quantities greater than 5% had significant ($p \leq 0.05$) negative effects on the physical and sensory properties and overall acceptability of the cookies. The 8 composite flour blends generated (w/w) using SF:CBF:SM were coded as SF50 (50:45:5), SF55 (55:40:5), SF60 (60:35:5), SF65 (65:30:5), CBF50 (45:50:5), CBF55 (40:55:5), CBF60 (35:60:5), and CBF65 (30:65:5), while control sample was 100% wheat flour (WF_{100}). Each blend was thoroughly mixed using a laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK), packaged in polyethylene bags, placed into separate plastic containers with lids and stored at 4 °C from where samples were taken for cookie preparation and further analysis.

Preparation of cookies

Composite cookies coded as SC50, SC55, SC60, SC65, CBC50, CBC55, CBC60 and CBC65 were prepared from the corresponding flour blends, while control cookie (WC_{100}) was prepared from the control flour (WF_{100}). Recipe (presented in Table 1) and methods for preparation were adopted from the basic gluten-free cookie recipe and procedure as described by Obeidat et al. (2012) with slight modification for some ingredients' inclusion and measurement. Briefly, sugar and shortening were thoroughly mixed manually for at least 2 min in a plastic mixing bowl using a wooden stirrer until a fluffy cream was obtained. Egg and milk (which had been dissolved in the appropriate amount of water as predetermined in a

Table 1 Blend formulation and recipe for cookies production

	Sample codes								
	WF_{100} (control)	SF50	SF55	SF60	SF65	CBF50	CBF55	CBF60	CBF65
Wheat flour (g)	100	0	0	0	0	0	0	0	0
Sorghum flour (g)	0	50	55	60	65	45	40	35	30
Cardaba banana flour (g)	0	45	40	35	30	50	55	60	65
Defatted sesame seed meal (g)	0	5	5	5	5	5	5	5	5
Shortening (g)	36	36	36	36	36	36	36	36	36
Baking powder (g)	1	1	1	1	1	1	1	1	1
Salt (g)	1	1	1	1	1	1	1	1	1
Sugar (g)	40	40	40	40	40	40	40	40	40
Egg (1 whole)	1	1	1	1	1	1	1	1	1
Milk (g)	10	10	10	10	10	10	10	10	10

SF Sorghum flour, *CBF* Cardaba banana flour, *SM* Sesame seed meal flour, WF_{100} 100 wheat flour, SF50 - 50:45:5, SF55 - 55:40:5, SF60 - 60:35:5, SF65 - 65:30:5, CBF50 - 45:50:5, CBF55 - 40:55:5, CBF60 - 35:60:5, CBF65 - 30:65:5 of SF:CBF:SM, respectively

preliminary test trial) were added while mixing continued for another 40 min. Thereafter, the dry ingredients (flour, salt and baking powder) were gently added and mixed thoroughly to form consistent dough. The dough was further kneaded and rolled thinly on a clean sheeting board to a uniform thickness of 6 mm. A 50 mm diameter round cookie cutter was used in cutting the dough into uniform shape and size. The cut dough was placed on greased baking pans and baked at 180° C for about 15–20 min until the cookies turned golden brown. The control sample was prepared using the same recipe and procedures but with 100% WF. The cookies were allowed to cool at ambient temperature (25 ± 2° C) for 8–10 min, packed in dry low-density polyethylene bags, placed in appropriately labeled air-tight plastic containers and stored at 4° C.

Chemical analysis of flour blends and cookies

Determination of proximate and mineral compositions, dietary fibre and estimation of gross energy values

Moisture, crude protein, total ash, crude fibre and crude fat contents of the flours and cookies were determined using standard AOAC methods (AOAC 2005), while carbohydrate was estimated by difference (100 – Σother components). Mineral elements were determined using the dry-ashing method of AOAC (2012). The elements, calcium (Ca), iron (Fe) and zinc (Zn) were quantified using an atomic absorption spectrophotometer (model 205, Buck Scientific, USA), while K and Na were determined using a flame photometer (Corning EEL). The soluble and insoluble dietary fiber contents of the flours and cookies were determined using AOAC methods (AOAC 2005). Gross energy values of the samples on dry weight basis were estimated using Atwater's factors for protein (Protein × 4.0), fat (Fat × 9) and carbohydrate (Carbohydrate × 4) and reported as Kcal/ 100 g.

Determination of functional properties of cookies and flour blends

Cookies were oven-dried at 50° C and milled into flour for determination of functional properties. Flour blends and cookie flours were investigated for their water (WaC) and oil absorption capacities (OaC), foaming (FmC) and emulsification capacities (EmC) and bulk density (BD). WaC and OaC were determined according to the procedures of Omowaye-Taiwo et al. (2015). Briefly, about 1 g of each flour sample was suspended in 10 mL of water [for OaC determination, soybean oil (density 0.88 g mL^{-1}) was used] in a 15 mL centrifuge tube and mixed for 1 min at ambient temperature (25 ± 2° C). After 30 min, the mixtures were centrifuged at 1200×g for 30 min. Free water/oil after centrifugation was read directly from the graduated tube. WaC and OaC were calculated using the following equations:

$$\mathrm{WaC}\ (\%) = \frac{\text{Amount of water added} - \text{free water (mL)}}{\text{Weight of sample (g)}} \times \text{density of water} \times 100 \quad (1)$$

$$\mathrm{OaC}\ (\%) = \frac{\text{Amount of oil added} - \text{free oil (mL)}}{\text{Weight of sample (g)}} \times \text{density of oil} \times 100 \quad (2)$$

Foaming capacity (FmC) was determined as described by Sze-Tao and Sathe (2000) by dispensing 50 mL of distilled water into a 100 mL graduated cylinder with 2 g of each flour sample and whipped continuously to foam. The volume after 30 s recorded and foaming capacity was expressed as percentage increase in volume after 30 s and calculated as:

$$\mathrm{FmC}\ (\%) = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100 \tag{3}$$

Emulsion capacity (EmC) was determined using methods described by Fagbemi (1991). Weighed flour samples (2 g) was dispersed in 40 mL distilled water, mixed thoroughly and stirred continuously with addition of 10 mL vegetable oil added over a period of 5 min. The emulsion was dispensed into a graduated centrifuge tube, boiled for 15 min at 85° C and centrifuged until the oil volume separated remained constant. EmC was calculated using the following equation:

$$\mathrm{EmC}\ (\%) = \frac{\text{Volume of oil used} - \text{volume of oil separated}}{\text{Volume of oil used (mL)}} \times 100 \tag{4}$$

Bulk density was determined by weighing 5 g flour sample into a 10 mL graduated cylinder. The cylinder was tapped several times until a constant volume was achieved (Ferrari et al. 2013). Bulk density was calculated as:

$$\text{Bulk density}\ (\mathrm{g/mL}) = \frac{\text{Weight of sample}\ (\mathrm{g})}{\text{Volume of sample after tapping (ml)}} \tag{5}$$

Measurement of physical characteristics of the cookies

Physical characteristics were measured after baking and cooling of the cookies. The weight, diameter, thickness and spread factor of the cookies were measured according to approved methods of AACC (2000). Thickness (mm) was measured by stacking six cookies on top of each other and cookies were reshuffled to replicate measurement. On the other hand, diameter (mm) of cookies was obtained by placing six (6) cookies edge-to-edge horizontally and rotating at 90° angle to replicate determination. The spread factor was calculated using the equation:

$$\mathrm{SF} = \mathrm{D}/\mathrm{T} \tag{6}$$

D – Diameter
T – Thickness

Sensory evaluation of the cookies

The gluten-free cookies and control samples were evaluated using a 40-member untrained panel selected from students and staff of the Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria. The panel was selected based on procedures adopted from Ayo-Omogie et al. (2021) using criteria including good health, nonsmoker, non-allergic to sorghum, banana flour or sesame seed, willingness to participate, and passion/likeness for cookies. The cookies were evaluated 12 h after baking using a 9-point Hedonic scale rating where 9 represented like extremely and 1, dislike extremely. Samples were coded randomly, placed in clean white disposable plates and served to each panelist to evaluate for crust colour, crumb colour, flavour, texture/hardness, aftertaste and overall acceptability. The evaluation was performed in a well-lit spacious room with each panelist sitting some distance away from another to avoid interference. Panelists were served with portable water for rinsing their mouths between evaluations.

Statistical analysis

All analyses were carried out in triplicate and data obtained were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 20 (IBM, Armonk, NY, USA). Means were separated using Duncan's Multiple Range Test (DMRT) at 95% confidence level and results reported as mean ± standard deviation.

Results and discussion

Proximate composition of wheat flour and composite flour blends from sorghum, Cardaba banana and defatted sesame seed and the corresponding cookies

The proximate composition and energy values of sorghum:Cardaba banana:defatted sesame seed composite flour blends and cookies and 100% wheat flour and cookies are presented in Table 2. Moisture content of flour samples varied significantly ($p \leq 0.05$) from 7.05% in the control (WF_{100}) to 8.56% in CBF65 (30:65:5 SF:CBF:SM). These generally low values (being lower than ≤10 g/100 g) may imply potential keeping quality, shelf-stability and extended storability of the flour samples due to reduced susceptibility to moisture-dependent deteriorative microbiological and biochemical changes (Ayo-Omogie 2021). Interestingly, after

Table 2 Proximate composition (% DW basis) and energy value of sorghum-Cardaba banana-defatted sesame seed meal flour blends and cookies

Samples	Moisture content	Crude Protein	Total Ash	Crude Fibre	Crude Fat	Carbohydrate	Gross Energy (Kcal/100 g)
Flours							
WF_{100} (control)	7.05 ± 0.07^{d}	11.11 ± 0.01^{h}	1.74 ± 0.01^{d}	1.22 ± 0.01^{a}	4.21 ± 0.04^{h}	81.72 ± 0.13^{a}	398.25 ± 2.96^{f}
SF50	7.66 ± 0.05^{c}	16.26 ± 0.07^{d}	3.85 ± 0.02^{b}	3.56 ± 0.01^{e}	8.62 ± 0.19^{c}	67.71 ± 0.17^{f}	414.46 ± 0.85^{a}
SF55	7.45 ± 0.04^{e}	18.74 ± 0.11^{c}	3.82 ± 0.03^{b}	3.97 ± 0.01^{h}	8.91 ± 0.01^{b}	64.56 ± 0.08^{g}	408.05 ± 1.78^{bc}
SF60	7.66 ± 0.04^{d}	19.98 ± 0.14^{b}	3.58 ± 0.01^{c}	3.89 ± 0.02^{c}	9.13 ± 0.01^{a}	63.42 ± 1.03^{h}	409.44 ± 1.11^{b}
SF65	7.65 ± 0.13^{cd}	20.42 ± 0.05^{a}	3.58 ± 0.02^{c}	4.61 ± 0.04^{d}	9.15 ± 0.08^{a}	62.24 ± 0.15^{h}	411.21 ± 2.49^{ab}
CBF50	7.76 ± 0.08^{c}	15.99 ± 0.18^{e}	3.84 ± 0.01^{ab}	3.25 ± 0.01^{g}	7.63 ± 0.15^{d}	69.29 ± 1.89^{def}	414.29 ± 1.77^{a}
CBF55	7.86 ± 0.07^{b}	15.09 ± 0.09^{f}	3.97 ± 0.06^{a}	3.29 ± 0.01^{f}	6.33 ± 0.09^{e}	71.32 ± 0.45^{d}	404.67 ± 1.09^{d}
CBF60	7.86 ± 0.02^{b}	11.40 ± 0.08^{g}	3.98 ± 0.02^{a}	3.11 ± 0.16^{b}	5.18 ± 0.16^{f}	76.33 ± 0.22^{c}	399.44 ± 2.25^{f}
CBF65	8.56 ± 0.01^{a}	10.96 ± 0.11^{hi}	3.97 ± 0.09^{a}	3.04 ± 0.11^{f}	4.60 ± 0.19^{g}	77.43 ± 0.09^{b}	403.18 ± 0.43^{e}
Cookies							
WC_{100} (control)	3.91 ± 0.37^{b}	11.94 ± 0.25^{i}	1.56 ± 0.06^{g}	1.01 ± 0.25^{a}	10.53 ± 0.04^{e}	74.96 ± 0.28^{a}	441.99 ± 1.87^{a}
SC50	1.98 ± 0.28^{f}	20.54 ± 0.13^{e}	2.06 ± 0.16^{f}	3.37 ± 0.31^{a}	10.66 ± 0.09^{d}	63.37 ± 0.06^{f}	424.53 ± 0.68^{b}
SC55	1.83 ± 0.53^{f}	23.72 ± 0.36^{bc}	2.52 ± 0.05^{d}	3.34 ± 0.05^{e}	11.72 ± 0.04^{a}	58.70 ± 0.52^{gh}	423.08 ± 1.71^{bc}
SC60	1.88 ± 0.13^{f}	23.89 ± 0.12^{b}	2.55 ± 0.19^{de}	3.38 ± 0.03^{de}	11.30 ± 0.03^{bc}	58.88 ± 0.61^{g}	420.78 ± 1.68^{de}
SC65	2.43 ± 0.05^{d}	24.25 ± 0.25^{a}	2.01 ± 0.12^{f}	3.41 ± 0.15^{d}	11.42 ± 0.51^{ab}	58.91 ± 0.44^{g}	422.27 ± 1.82^{cd}
CBC50	1.89 ± 0.41^{f}	21.93 ± 0.72^{d}	3.34 ± 0.04^{c}	3.37 ± 0.02^{de}	10.66 ± 0.03^{d}	60.70 ± 0.10^{e}	423.36 ± 0.38^{c}
CBC55	3.64 ± 0.44^{c}	18.91 ± 0.65^{f}	2.46 ± 0.01^{e}	3.72 ± 0.12^{bc}	9.83 ± 0.15^{f}	65.08 ± 0.52^{d}	419.58 ± 2.02^{def}
CBC60	5.21 ± 0.71^{a}	15.89 ± 0.82^{g}	3.60 ± 0.15^{b}	3.82 ± 0.23^{b}	9.54 ± 0.14^{g}	67.15 ± 0.27^{c}	415.03 ± 3.4^{fg}
CBC65	2.24 ± 0.19^{e}	14.39 ± 0.49^{h}	3.89 ± 0.05^{a}	3.77 ± 0.09^{b}	9.39 ± 0.10^{gh}	68.56 ± 0.48^{b}	416.61 ± 0.75^{g}
*RDA	≤ 10.00	> 14.00	< 3.00	< 5.00	10.00–25.00	64.00	344–425

Mean ± SD, $n = 3$. Mean values followed by different superscripts within columns are significantly different by Duncan's multiple range tests ($P \leq 0.05$) as separately compared across flour blends and cookies

Keys: WF_{100} 100% wheat flour (control), WC_{100} 100% wheat cookies (control), SF50 - 50:45:5, SF55 - 55:40:5, SF60 - 60:35:5, SF65 - 65:30:5, CBF50 - 45:50:5, CBF55 - 40:55:5, CBF60 - 35:60:5, CBF65 - 30:65:5 of SF:CBF:SM, respectively, while F is replaced with C accordingly for corresponding cookies

**RDA* Recommended Dietary Allowance (Suitor & Murphy 2013; WHO/FAO Consultation 2003)

cookie production, the moisture content of all composite cookies were significantly ($p \leq 0.05$) lower than the control WC_{100}, except sample CBC60 (35:60:5 SF:CBF:SM) which had the highest value of 5.21%. This may be an indication that the composite flour blends which consisted of 3 flours had higher requirements for water to hydrate their starch granules so as to aid optimum swelling during baking. In addition, the higher fibre constituents in the composite blends may have resulted in more competition for available water with other macro constituents of the flour during hydration to attain the required dough consistency (Lin et al. 2021; Kotsiou et al. 2022). These lower values are however advantageous to promote longer shelf-life of the composite cookies as compared to 100% wheat-flour cookies.

The composite flour blends and cookies were 35.82–83.80% and 20.52–103.10% significantly higher ($p \leq 0.05$) in protein than the control flour (WF_{100}) and cookie (WC_{100}), except for sample CBF65 which had a comparatively lower value of 10.96 to 11.11% in WF_{100}. Similarly, the composite flour blends had significantly ($p \leq 0.05$) higher fat and ash contents than WF_{100}, while carbohydrate content was higher in the control samples. The relatively higher protein content may be due to the inclusion of defatted sesame meal (SM) which has been previously reported to be rich in protein and essential amino acids (Demirhan & Özbek 2013; Dossou et al. 2022). This is consistent with findings reported in plantain-sesame cookies (Chinma et al. 2012), yellow cassava-sesame-fortified extruded snacks (Olorode & Sobowale 2021) and wheat-sesame biscuits (Gernah & Anyam 2014). This significant increase ($p \leq 0.05$) would enrich the nutrient profile of sorghum-based gluten-free flours and cookies, thereby helping to meet protein and nutrient requirements for celiac patients and other non-gluten consumers who are often prone to nutritional deficiency.

The relatively high protein content of the composite cookies (> 14% RDA) may indicate their potential to promote growth, development and repair of tissues in both children and adults since protein is one of the most essential macronutrients required for proper functioning and growth of the human body (Mulla et al. 2022; WHO/FAO Consultation 2003). Thus, these composite cookies could be used as low-cost sources for alleviating protein-energy malnutrition in at-risk communities in sub-Saharan Africa among school-age children (especially) and also adults who consume cookies both as side meal and snacks. The higher fat content of the composite samples may be due to sesame seed flour inclusion which although was defatted, may significantly have influenced this increase. Previous findings have reported that undefatted sesame seed flour contained 34.63–49.55% fat, while the defatted flour contains 18.50% fat (Anilakumar et al. 2010; Umbur et al. 2021; Zebib et al. 2015). The addition of defatted sesame flour was reported to increase fat content of wheat bread, plantain-based cookies and amaranth flours (Chinma et al. 2012; Ogundele et al. 2022; Umbur et al. 2021). The significant ($p \leq 0.05$) higher fat values of the cookies as compared to their corresponding flour samples may be due to shortening used in the cookie production. On the other hand, the composite cookies had relatively higher fat content (ranging from 10.66–11.72%) than the control WC_{100} with a value of 10.53%, except for samples CBC55-CBC65 (with values of 9.39–9.83%). Their lower values may be due to higher inclusion levels of CBF in the composition derived from its low lipid content (Ayo-Omogie et al. 2010, 2021). The increased fat content may impart positively on the flavour and texture of bakery products thereby enhancing consumer acceptability.

The micronutrient-rich content of the constituent flours in the composite samples may account for their higher ash content. Thus, reemphasizing the better nutritional quality of alternative flours formulated from blends of different plant materials as compared to 100% wheat flour. The destructive effect of high temperature used during baking on nutrients may be responsible for the decrease in ash content of cookies as compared to corresponding flours. The energy value of the control cookie (WC_{100}) was significantly higher ($p \leq 0.05$) (441.99 Kcal/100 g) than the composite cookies (415.03–424.53 Kcal/100 g). This may suggest a greater contribution of carbohydrate to the energy value of the control samples while those of composite samples were majorly contributed by protein and fat which were higher in these samples. This may have advantage for improving the protein-energy density of the samples and may be advantageous for controlling/preventing overweight and obesity in adults. In addition, these cookies may find use as high quality protein, energy-dense supplementary ready-to-eat food for children in at-risk communities in Africa since children require quality protein and energy-dense foods for optimum growth, development and physical activities. Except for the control cookie, all the flour and cookie samples fell within the recommended WHO/FAO standard of 344–425 Kcal/day (WHO/FAO Consultation 2003). As such, these samples may be able to meet up to 50–100% of daily energy requirements for both children and adults.

Mineral composition and dietary fibre contents of flours and cookies from blends of sorghum, Cardaba banana and sesame seed meal

Results obtained for mineral composition revealed significantly higher ($P \leq 0.05$) mineral profile of the composite samples as compared to control samples (Table 3). This is in correlation with observed higher ash content earlier reported (Table 2). Minerals are important components which play vital roles in metabolism regulation and optimal functioning of the immune system, thereby influencing susceptibility to infections and development of chronic diseases (Calder et al. 2020; Maggini et al. 2018; Kim & Choi 2013). This higher mineral profile is consistent with previous reports that alternate gluten-free flours from cereals, legumes and fruits possess higher micronutrient contents than flour made solely from wheat due to the complementation of different nutritional constituents from the blending of plant raw materials (Chinma et al. 2015; Rai et al. 2018; Sanni et al. 2020; Hager et al. 2012). Potassium observed to be the most predominant mineral element in the composite samples followed a dose-dependent trend with higher amounts of CBF resulting in higher values. Our previous findings (Ayo-Omogie et al. 2010, 2021) revealed that potassium is the most predominant mineral element in Cardaba banana which is in tandem with reports that other cooking *Musa* species such as plantain have K as its predominant mineral element (Odenigbo et al. 2013; Osundahunsi 2009). The high content of K (86.71–217.02 mg/100 g) obtained in this study may assist in promoting increased iron utilization in the body. In association with sodium, potassium has also been reported to help in regulation of the body pH, muscle and nerve signals, body fluids, glucose assimilation, and protein reservation during cell development (Omoba & Omogbemile 2013). The higher K content as compared to Na may account for the low Na/K ratios (ranging from 0.02–0.77) obtained here. Since these values are lower than the critical Na/K ratio ($\leq$1.00), these flours and cookies could be suitable alternatives for individuals managing high blood pressure.

The CBF and SM may have contributed to the significantly high ($P \leq 0.05$) Ca content of the composite flour blends and cookies (38.43–50.78 mg/100 g and 57.5–66.05 mg/100 g, respectively), being rich sources of Ca (Ayo-Omogie et al. 2010; Onsaard 2012). This may be advantageous in the prevention of osteoporosis and osteoarthritis which are disorders associated with both Type-1 and Type-2 diabetes mellitus, respectively,

Table 3 Mineral element composition, Na/K ratio and dietary fibre contents of sorghum-Cardaba banana-defatted sesame seed meal composite flour blends and cookies

Samples	Mineral element composition (mg/100 g)					Na/K	Dietary fibre (g/100 g)			
	Ca	Fe	K	Na	Zn		SDF	IDF	TDF	IDF/SDF ratio
Flours										
WF_{100} (control)	1.13 ± 0.11^{h}	1.03 ± 0.01^{b}	43.65 ± 0.21^{i}	6.85 ± 0.07^{b}	0.28 ± 0.01^{g}	0.16	2.25 ± 0.01^{e}	5.14 ± 0.03^{i}	7.39 ± 0.07^{h}	2.28
SF50	43.01 ± 0.01^{e}	0.26 ± 0.01^{f}	162.25 ± 0.35^{e}	5.91 ± 0.01^{c}	0.89 ± 0.01^{c}	0.04	3.12 ± 0.01^{a}	20.97 ± 0.02^{e}	24.09 ± 0.04^{e}	6.72
SF55	40.13 ± 0.02^{f}	0.33 ± 0.04^{e}	152.02 ± 0.04^{f}	5.51 ± 0.01^{d}	0.77 ± 0.01^{d}	0.04	3.19 ± 0.01^{a}	18.60 ± 0.13^{f}	21.80 ± 0.07^{f}	5.83
SF60	44.73 ± 0.14^{d}	0.47 ± 0.01^{d}	129.02 ± 0.04^{g}	7.81 ± 0.01^{a}	0.94 ± 0.01^{b}	0.06	3.09 ± 0.02^{b}	17.72 ± 0.01^{h}	20.81 ± 0.02^{g}	5.74
SF65	45.03 ± 0.04^{c}	0.51 ± 0.01^{d}	113.02 ± 0.04^{h}	3.08 ± 0.35^{gh}	0.46 ± 0.03^{e}	0.03	3.00 ± 0.04^{b}	18.86 ± 0.01^{g}	21.86 ± 0.12^{f}	6.27
CBF50	40.11 ± 0.01^{f}	0.63 ± 0.01^{c}	163.01 ± 0.01^{d}	2.73 ± 0.04^{h}	0.43 ± 0.04^{e}	0.02	3.18 ± 0.02^{a}	21.08 ± 0.09^{de}	24.27 ± 0.19^{d}	6.63
CBF55	49.92 ± 0.02^{b}	0.54 ± 0.01^{d}	188.02 ± 0.03^{c}	3.80 ± 0.01^{f}	0.73 ± 0.01^{d}	0.02	3.06 ± 0.17^{abc}	21.94 ± 0.14^{c}	25.01 ± 0.01^{c}	7.17
CBF60	38.43 ± 0.04^{g}	0.61 ± 0.01^{c}	191.02 ± 0.04^{b}	3.23 ± 0.04^{g}	0.38 ± 0.02^{ef}	0.02	2.91 ± 0.01^{c}	24.46 ± 0.04^{b}	27.37 ± 0.01^{b}	8.41
CBF65	50.78 ± 0.13^{a}	1.26 ± 0.02^{a}	217.02 ± 0.04^{a}	5.13 ± 0.04^{e}	1.02 ± 0.05^{a}	0.02	2.73 ± 0.02^{d}	26.14 ± 0.05^{a}	28.87 ± 0.01^{a}	9.58
Cookies										
WC_{100} (control)	39.11 ± 0.41^{h}	1.28 ± 0.01^{g}	37.43 ± 0.19^{i}	32.21 ± 1.37^{h}	0.43 ± 0.05^{c}	0.87	2.35 ± 0.02^{e}	5.38 ± 0.08^{i}	7.73 ± 0.54^{i}	2.29
SC50	66.05 ± 0.07^{a}	1.51 ± 0.03^{cd}	93.70 ± 0.82^{e}	64.00 ± 0.01^{c}	0.85 ± 0.02^{a}	0.68	2.75 ± 0.01^{c}	15.47 ± 0.11^{e}	18.22 ± 0.11^{e}	5.63
SC55	63.41 ± 0.14^{e}	1.48 ± 0.02^{d}	89.00 ± 0.79^{f}	68.91 ± 0.07^{a}	0.75 ± 0.01^{b}	0.77	2.96 ± 0.03^{b}	13.56 ± 0.02^{g}	16.52 ± 0.07^{g}	4.58
SC60	57.50 ± 0.13^{g}	1.41 ± 0.02^{de}	86.71 ± 0.26^{h}	60.21 ± 0.04^{e}	0.71 ± 0.01^{b}	0.69	2.98 ± 0.14^{b}	12.48 ± 0.21^{h}	15.46 ± 0.06^{h}	4.19
SC65	65.10 ± 0.05^{c}	1.36 ± 0.03^{ef}	87.43 ± 0.09^{g}	61.41 ± 0.10^{d}	0.81 ± 0.10^{ab}	0.70	3.07 ± 0.02^{a}	14.90 ± 0.10^{f}	17.97 ± 0.11^{ef}	4.85
CBC50	63.57 ± 0.17^{e}	1.46 ± 0.01^{d}	100.7 ± 0.41^{cd}	66.51 ± 0.27^{b}	0.83 ± 0.11^{ab}	0.66	2.71 ± 0.02^{c}	17.87 ± 0.01^{d}	20.58 ± 0.42^{d}	6.59
CBC55	65.71 ± 0.14^{b}	1.54 ± 0.01^{c}	101.02 ± 0.39^{c}	60.41 ± 0.81^{e}	0.78 ± 0.01^{b}	0.60	2.67 ± 0.02^{c}	19.03 ± 0.07^{c}	21.70 ± 0.21^{c}	7.13
CBC60	62.80 ± 0.04^{f}	1.62 ± 0.02^{b}	107.02 ± 0.14^{b}	44.71 ± 0.17^{g}	0.69 ± 0.01^{b}	0.42	2.57 ± 0.01^{d}	19.95 ± 0.15^{b}	22.52 ± 0.08^{b}	7.76
CBC65	64.11 ± 0.07^{d}	1.74 ± 0.01^{a}	114.02 ± 0.30^{a}	57.31 ± 0.43^{f}	0.73 ± 0.02^{b}	0.50	2.51 ± 0.04^{d}	21.51 ± 0.18^{a}	24.02 ± 0.16^{a}	8.57
*RDA	19–8081	10–15	19–502	30–134	0.23–2.10	< 1.0			**20–25 g	

Mean ± SD, $n = 3$. Mean values followed by different superscripts within columns are significantly different by Duncan's multiple range tests ($P \leq 0.05$) as separately compared across flour blends and cookies

Keys: WF_{100} 100% wheat flour (control), WC_{100} 100% wheat cookies (control), SF50 - 50:45:5, SF55 - 55:40:5, SF60 - 60:35:5, SF65 - 65:30:5, CBF50 - 45:50:5, CBF55 - 40:55:5, CBF60 - 35:60:5, CBF65 - 30:65:5 of SF:CBF:SM, respectively, while F is replaced with C accordingly for corresponding cookies, *SDF* Soluble dietary fibre, *IDF* Insoluble dietary fibre, *TDF* Total dietary fibre

**RDA* Recommended Dietary Allowance (Suitor & Murphy 2013; WHO/FAO Consultation 2003)

**Dhingra et al. (2012)

resulting from thinning of the bones and degeneration of joint cartilage (Lee et al. 2007; Romero-Díaz et al. 2021). Similarly, Zn content was significantly higher ($P \leq 0.05$) in the composite flours and cookies as compared to control samples. Similarly, Zn content was significantly higher ($P \leq 0.05$) in the composite flours and cookies as compared to control samples. This may be attributed to the inclusion of sesame meal. Legumes and nuts have been reported to be rich sources of zinc. Apparently, these samples may be advantageous in the regulation of many physiological processes, prevention of metabolic disorders and in boosting the immune system of consumers based on the essentiality of Zn in regulating physiological processes and in the modulation of the immune system. These are vital for reducing risks to many infectious diseases such as COVID-19 (Prasad 2008; Weyh et al. 2022; WHO/FAO Consultation 2003).

Results showed that SDF, IDF and TDF of the composite flours and cookies were significantly ($p \leq 0.05$) higher by 21.33–41.78, 177.74–309.72 and 141.14–234.53%, and 6.81–30.64, 149.6–330.2 and 110.34–226.8% than the control flour and cookie, respectively. This may be partly attributable to the high DF content of unripe Cardaba banana being a rich source of dietary fibre (Adegbaju et al. 2021; Adeola & Ohizua 2018; Falodun et al. 2019; Ovando-Martinez et al. 2009) and also whole grain sorghum with relatively high DF content (Adebo 2020; Barrett et al. 2020; Prasadi & Joye 2020). Also, sesame meal may have contributed since defatted oilseed, meal or cakes have been shown to be rich sources of dietary fibre (Nevara et al. 2021; Trinidad et al. 2010). However, results also revealed that CBF quantity played the most important contributory role to the higher IDF values where samples with the highest amount of CBF had the highest IDF and TDF values, while SDF contents decreased. This is consistent with reports of higher IDF and lower SDF values of Cardaba banana flour previously reported (Falodun et al. 2019). Thus, confirming reports that, apart from whole grains, fruit flours (including unripe bananas) are the most significant sources of dietary fibre to diets (Adegbaju et al. 2021; Aparicio-Saguilán et al. 2006; Ovando-Martinez et al. 2009).

Similar trends were reported by Adeola and Ohizua (2018) in cookies made from blends of Cardaba banana, pigeon pea and sweet potato flour. Although closely-related TDF values (11.73–19.05 g/100 g) were reported in this study, higher values reported here (15.46–24.02 g/100 g) may be due to larger quantity of Cardaba banana flour used in this present study. However, other researchers have reported lower DF values in composite whole grain sorghum- and pearl millet-soya sour biscuits (15.0–16.0 g/100 g) (Omoba et al. 2015) and wheat-banana cookies (6.6–10.9 g/100 g) (Agama-Acevedo et al. 2012). On the other hand, significant decrease ($P \leq 0.05$) observed in DF values after production of cookies may be attributed to cooking losses associated with the high-fibre ingredients of the composite samples. According to Cleary and Brennan (2006) and Ovando-Martinez et al. (2009), partial or complete replacement of wheat with fibre-rich materials and non-gluten flours dilute gluten strength, bringing about negative changes to quality of products (including increased cooking losses) and weakening of the overall structure of the final product. This loss in structure may promote leaching out of more solids from the product during preparation. This may explain the observed increase in the control cookie (WC_{100}) as compared to its corresponding flour (WF_{100}) since it was neither gluten-free nor gluten-reduced. Despite this decrease, both the composite sorghum-Cardaba banana-defatted sesame flours and cookies may be considered as high-fibre foods [being higher than 6 g dietary fibre/100 g (European Commission 2007)] which could serve as functional fibre-rich ingredients/food sources to meet the Dietary Reference Intake (DRI) (USDA Food and Nutrition Information Center). These fibre-rich flours and cookies may aid improved nutritional status and maintenance of consumers' health. Based on the hyperglycemic-reducing property of DF, these samples may be termed as low GI food and may possess potential to decrease glucose and insulinemic responses, and lowered risk factors of colon cancer, diabetes mellitus, cardiovascular diseases and other non-communicable diseases (NCDs). In addition, the high IDF contents in the composite cookies may significantly promote laxation and aid in preventing and/or managing the prevalence and severity of constipation and hemorrhoids which are conditions commonly associated with bakery products prepared from refined wheat flour (Cummings 2001; Ho et al. 2000; Prasadi & Joye 2020; Soliman 2019).

Functional properties of blended sorghum-Cardaba banana-defatted sesame seed meal and cookie flours

Results obtained for water and oil absorption capacities, foaming and emulsification capacities and bulk density of the flour blends and cookies in comparison to 100% WF and WC are presented in Table 4. Water absorption capacity (WaC) varied significantly ($p \leq 0.05$) among the composite flours. Higher values (ranging from 175 to 250%) were obtained for the composite flour blends as compared to the control WF_{100} (155.0%), although sample SF65 (65:30:5 SF:CBF:SM) had a relatively lower value of 153%. These variations are suggestive of the contributory effects of blending ratios and compositional differences on WaC of the samples. The higher WaC of the composite flours may have partly resulted

Table 4 Functional properties of flours from functional cookies and blends of sorghum-Cardaba banana-defatted sesame seed meal

Samples	BD (g/mL)	WaC (%)	OaC (%)	FmC (%)	EmC (%)
Flours					
WF_{100} (control)	0.91 ± 0.08^{a}	155.00 ± 1.07^{h}	170.00 ± 0.35^{a}	4.13 ± 0.07^{gh}	14.66 ± 0.05^{a}
SF50	0.74 ± 0.01^{cd}	199.50 ± 3.36^{e}	145.00 ± 1.21^{e}	7.04 ± 0.11^{bc}	6.88 ± 0.04^{e}
SF55	0.77 ± 0.01^{c}	184.00 ± 1.06^{f}	150.00 ± 2.37^{d}	7.14 ± 0.02^{b}	7.01 ± 0.01^{d}
SF60	0.74 ± 0.02^{cd}	175.00 ± 2.85^{g}	160.00 ± 1.01^{c}	7.14 ± 0.01^{b}	7.51 ± 0.03^{c}
SF65	0.81 ± 0.01^{b}	153.00 ± 3.06^{hi}	165.30 ± 2.21^{b}	8.82 ± 0.12^{a}	7.63 ± 0.04^{b}
CBF50	0.83 ± 0.02^{b}	200.00 ± 2.14^{d}	144.00 ± 0.39^{f}	5.86 ± 0.05^{d}	6.82 ± 0.01^{ef}
CBF55	0.77 ± 0.01^{c}	202.00 ± 1.03^{c}	138.30 ± 0.95^{g}	5.63 ± 0.04^{e}	6.81 ± 0.02^{ef}
CBF60	0.71 ± 0.03^{cd}	225.00 ± 2.47^{b}	136.50 ± 0.57^{h}	4.29 ± 0.01^{f}	6.81 ± 0.07^{ef}
CBF65	0.74 ± 0.01^{cd}	250.00 ± 1.91^{a}	120.00 ± 0.59^{i}	4.06 ± 0.01^{h}	6.80 ± 0.02^{ef}
Cookie flours					
WC_{100} (control)	0.49 ± 0.02^{e}	27.00 ± 0.32^{c}	25.50 ± 0.71^{a}	0.00 ± 0.00	4.20 ± 0.03^{c}
SC50	0.55 ± 0.03^{de}	21.50 ± 0.33^{g}	19.00 ± 0.71^{e}	0.00 ± 0.00	5.25 ± 0.07^{a}
SC55	0.59 ± 0.02^{cd}	23.00 ± 0.01^{e}	19.80 ± 0.00^{d}	0.00 ± 0.00	3.60 ± 0.01^{d}
SC60	0.56 ± 0.03^{d}	19.00 ± 0.02^{h}	21.25 ± 0.35^{c}	0.00 ± 0.00	2.50 ± 0.02^{f}
SC65	0.59 ± 0.02^{cd}	24.50 ± 0.31^{d}	23.00 ± 0.00^{b}	0.00 ± 0.00	3.05 ± 0.04^{e}
CBC50	0.74 ± 0.03^{a}	22.50 ± 0.25^{f}	18.00 ± 0.01^{f}	0.00 ± 0.00	2.50 ± 0.10^{f}
CBC55	0.64 ± 0.03^{bc}	25.00 ± 1.30^{c}	17.75 ± 0.35^{fg}	0.00 ± 0.00	3.60 ± 0.04^{d}
CBC60	0.70 ± 0.04^{ab}	35.50 ± 0.12^{b}	17.00 ± 0.00^{h}	0.00 ± 0.00	2.05 ± 0.07^{g}
CBC65	0.65 ± 0.03^{bc}	38.00 ± 0.50^{a}	16.25 ± 0.35^{i}	0.00 ± 0.00	4.45 ± 0.02^{b}

Mean ± SD, $n = 3$. Mean values followed by different superscripts within columns are significantly different by Duncan's multiple range tests ($P \leq 0.05$) as separately compared across flour blends and cookies

Keys: WF_{100} 100% wheat flour (control), WC_{100} 100% wheat cookies (control), SF50 - 50:45:5, SF55 - 55:40:5, SF60 - 60:35:5, SF65 - 65:30:5, CBF50 - 45:50:5, CBF55 - 40:55:5, CBF60 - 35:60:5, CBF65 - 30:65:5 of SF:CBF:SM, respectively, while F is replaced with C accordingly for corresponding cookies, *BD* Bulk density, *WaC* Water absorption capacity, *OaC* Oil absorption capacity, *FmC* Foaming capacity, *EmC* Emulsification capacity

from the addition of defatted sesame seed flour which are known to possess higher water absorption capacity due to the relative abundance of polar amino acid residues known to be hydrophilic (have higher affinity for water) (Jan et al. 2022; Kambabazi et al. 2022; Mohammed et al. 2012; Ojo et al. 2017). In addition, the higher DF contents of the composite flours may have partly contributed because DF possesses water- and oil-holding capacity, which are desirable technological properties for development of novel food produ (Hua et al. 2019); Schneeman 2008). Apparently, this high WaC of the composite flours may be suggestive of their suitability for manufacture of acceptable GF bakery products (Awuchi et al. 2019; Ojo et al. 2017). In addition, the high WaC of the flours may enhance reconstitution of the flours and textural integrity of its pastes (Marcel et al. 2021), thus, making them useful in products where reconstitution and paste formation are required. Baking caused a significant ($P \leq 0.05$) 84.8–87.58% decrease in the WaC of the cookie flours in relation to the flour blends probably due to protein denaturation and starch gelatinization during baking, thereby leading to solubilization or leaching of the amylose fraction (Ayo-Omogie et al. 2021).

Similarly, oil absorption capacity (OaC) of the flour blends were significantly higher ($p \leq 0.05$) than their corresponding cookie flours. Although protein denaturation (which could have occurred during baking) is reported to enhance fat absorption, severe denaturation, may destroy hydrophobic domains and subsequently reduce fat binding (Hutton & Campbell 1981). In contrast to WaC, the control flour (WF_{100}) (170%) and cookie (WC_{100}) (25%) had significantly higher ($P \leq 0.05$) OaC than the composite flour blends (120–165%) and cookies (16–23%). This could imply that wheat gluten protein and its amino acid composition possess more apolar side chains and higher hydrophobicity (which promote higher fat absorption) than the proteins and amino acids present in the composite samples. This corroborates the earlier observation that the possible presence of more polar amino acid residues in the composite samples could have influenced their relatively higher WaC. Jan et al. (2022) reported similarly in low-gluten wheat pretzels substituted with rice flour. As such, the higher OaC may be one of the factors that confers on gluten-based flour its excellent baking properties since high fat absorption is a desirable property during baking. Thus, these flours may find useful application in the production of acceptable GF baked foods with enhanced mouthfeel and flavours since fat assists in flavor retention, increases mouthfeel and improves palatability of bakery products (Haruna et al. 2019; Iwe et al. 2016; Suresh & Samsher 2013).

The control WF_{100} had the highest (0.91 g/mL) bulk density (BD) while values obtained for the composite flours were not significantly different ($P > 0.05$) (0.71–0.77 g/mL) except sample CBF50 (0.83 g/mL) (Table 4). Baking significantly ($P \leq 0.05$) decreased these values with WC_{100} having the lowest value of 0.49 g/mL as compared to the composite cookies with values ranging from 0.55–0.74 g/mL (Table 4). Although all the samples had low foaming capacity, the composite flour blends (4.29–8.82%) had significantly higher ($P \leq 0.05$) values than the control WF_{100} (4.13%). This may be linked to their higher protein content and presence of surface-active flexible protein molecules which decrease surface tension at the water-air interface, thereby enabling higher foam formation, formation of a continuous, cohesive film around the air bubbles in the foam and permitting hydrophobic interactions which are relevant in bakery products preparation (Asif-Ul-Alam et al. 2014; Chinma et al. 2009; Kaushal et al. 2012). Progressive addition of CBF decreased FmC probably due to its low protein content. On the other hand, emulsion capacity (EmC) was significantly higher ($P \leq 0.05$) in the control wheat flour (WF_{100}) (14.66%) as compared to the composite flour blends (6.80–7.63%). Progressive inclusion of CBF in the composite flours resulted in higher EmC except for samples SF55-SF65 which had the highest amount of sorghum flour inclusion (Table 4). Similar findings were reported by Ubbor et al. (2022) where increasing inclusion of acha resulted in increased emulsion capacity of wheat:acha:orange-fleshed sweet potato composite flour blends.

Physical properties and sensory attributes of sorghum:Cardaba banana:defatted sesame meal cookies

The physical properties and sensory attributes of composite cookies formulated from blends of sorghum, Cardaba banana and defatted sesame seed as compared to 100% wheat cookies are presented in Table 5. Thickness of the composite cookies (ranging from 4.10–4.20 mm) was not significantly different ($P > 0.05$) from the control (4.10 mm), except in sample SC50 (50:45:5 SF:CBF:SM) with a value of 4.40 mm. Diameter of the composite cookies (20.10–20.20 mm) did not vary significantly ($P > 0.05$) from the control (WC_{100}–21.50 mm), except sample CBC65 (30:65:5 SF:CBF:SM) with the highest value (24.0 mm) and closely followed by CBC60 (35:60:5 SF:CBF:SM) (22.50 mm). On the other hand, the weights of the samples varied significantly ($P \leq 0.05$) from 7.06–8.45 g with the control (WC_{100}) being the lightest and sample SC65 (65:30:5 SF:CBF:SM) the heaviest. These results indicate that samples with the largest amounts of CBF inclusion had relatively higher diameter and this may be attributed to the higher starch content of CBF in comparison to sorghum and sesame. Low starch content and higher amounts of crude fibre are reported to cause smaller dimensions in cookies (Altan et al. 2009). This agrees with the observations in the present study where samples with the lowest amounts of carbohydrate and highest crude fibre (Table 2) had the smallest diameter.

Higher sorghum flour inclusion seemed to have a positive influence on the weight of the cookies [except in samples SC55 (55:40:5 SF:CBF:SM) and CFC50 (45:50:5 SF:CBF:SM)]. This may be linked with the protein contents of the samples where those with larger amounts

Table 5 Physical and sensory properties of sorghum-Cardaba banana-defatted sesame seed meal cookies

	WC_{100} (Control)	SC50	SC55	SC60	SC65	CBC50	CBC55	CBC60	CBC65
Physical characteristics									
Thickness (mm)	4.10 ± 0.01^{c}	4.40 ± 0.01^{a}	4.10 ± 0.01^{c}	4.10 ± 0.04^{c}	4.10 ± 0.02^{c}	4.20 ± 0.01^{b}	4.10 ± 0.01^{c}	4.10 ± 0.01^{c}	4.20 ± 0.14^{bc}
Diameter (mm)	21.50 ± 0.70^{c}	20.40 ± 0.10^{c}	20.20 ± 0.10^{c}	20.10 ± 0.10^{c}	20.10 ± 0.10^{c}	20.40 ± 0.20^{c}	20.40 ± 0.10^{c}	22.50 ± 0.10^{b}	24.00 ± 0.10^{a}
Weight (g)	7.06 ± 0.01^{f}	8.05 ± 0.07^{c}	8.10 ± 0.14^{bc}	8.28 ± 0.04^{b}	8.45 ± 0.07^{a}	8.18 ± 0.11^{bc}	7.88 ± 0.11^{d}	7.85 ± 0.01^{d}	7.75 ± 0.21^{de}
Spread ratio	5.25 ± 0.35^{bc}	4.65 ± 0.16^{e}	4.98 ± 0.14^{bc}	4.93 ± 0.14^{cd}	4.89 ± 0.19^{cd}	4.92 ± 0.49^{bc}	4.99 ± 0.06^{cd}	5.51 ± 0.79^{ab}	5.73 ± 0.01^{b}
Sensory attributes									
Crust colour	7.73 ± 0.03^{a}	6.40 ± 0.05^{bc}	6.60 ± 0.13^{b}	5.86 ± 0.05^{f}	6.20 ± 0.02^{d}	6.53 ± 0.04^{b}	6.00 ± 0.03^{e}	5.80 ± 0.08^{fg}	5.60 ± 0.02^{h}
Crumb colour	7.33 ± 0.11^{a}	6.20 ± 0.07^{c}	6.13 ± 0.01^{d}	5.73 ± 0.05^{f}	6.40 ± 0.01^{b}	6.13 ± 0.04^{d}	6.07 ± 0.07^{de}	5.60 ± 0.04^{g}	5.27 ± 0.06^{h}
Flavour	6.39 ± 0.06^{c}	5.80 ± 0.09^{de}	5.87 ± 0.05^{de}	5.67 ± 0.13^{e}	5.40 ± 0.04^{f}	5.93 ± 0.18^{d}	6.40 ± 0.02^{c}	6.60 ± 0.05^{b}	6.73 ± 0.02^{a}
Texture/Hardness	7.33 ± 0.07^{a}	6.33 ± 0.03^{d}	5.87 ± 0.15^{g}	6.00 ± 0.03^{e}	6.27 ± 0.07^{d}	5.93 ± 0.03^{fg}	5.87 ± 0.02^{g}	6.80 ± 0.04^{c}	6.89 ± 0.06^{b}
Aftertaste	6.00 ± 0.05^{f}	6.20 ± 0.02^{e}	6.00 ± 0.01^{f}	5.87 ± 0.03^{g}	5.53 ± 0.05^{h}	6.73 ± 0.04^{c}	6.60 ± 0.03^{d}	6.93 ± 0.04^{b}	7.13 ± 0.06^{a}
Overall acceptability	6.47 ± 0.06^{d}	6.33 ± 0.01^{e}	5.33 ± 0.07^{g}	6.20 ± 0.05^{f}	6.27 ± 0.03^{f}	6.47 ± 0.01^{d}	6.73 ± 0.02^{c}	6.93 ± 0.07^{b}	7.67 ± 0.08^{a}

Mean ± SD, $n = 3$. Mean values followed by different superscripts within rows are significantly different by Duncan's multiple range tests ($P \leq 0.05$)

Keys: WC_{100} 100% wheat cookies (control), SC50 - 50:45:5, SC55 - 55:40:5, SC60 - 60:35:5, SC65 - 65:30:5, CBC50 - 45:50:5, CBC55 - 40:55:5, CBC60 - 35:60:5, CBC65 - 30:65:5 of SF:CBF:SM, respectively of sorghum had higher protein contents as compared to samples with larger amounts of CBF inclusion. Similar observations were made by Adeola and Ohizua (2018), Adeyemo et al. (2022) and Chinma et al. (2012) in unripe cooking banana:pigeon pea:sweet potato cookies, shallot-enriched plantain biscuits and unripe plantain:defatted sesame seed cookies, respectively. Results obtained showed that CBF inclusion had positive effect on the spread ratio, with samples containing the largest amounts of CBF (60–65%) having significantly higher ($P \leq 0.05$) values (5.51–5.73) than the control (5.25) and other composite cookies (4.65–4.89). Spread ratio is an important index used in measuring the quality of flour for preparation of biscuits and its ability to rise (Bala et al. 2015). Since biscuits with higher spread ratios are usually more desirable (Chauhan et al. 2016), sample CBC65 with 30:65:5 SF:CBF:SM may be the most preferred due to its highest spread ratio. As such, CBF may have played significant role in enhancing the cookie-making potential of sorghum flour and may thus explain the highest overall acceptability scores of this sample, which is an indication of the panelists' preference for this cookie as compared to the control or other composite cookies.

The generally high sensory scores (ranging from 5.27–7.67) is an indication of consumers' likeness and acceptability of the composite cookies. These values are similar to 5.40–7.35 reported by Gernah and Anyam (2014) in wheat:defatted sesame cookies, but higher than 4.79–7.04 reported in unripe cooking banana:pigeon pea:sweet potato cookies (Adeola & Ohizua 2018). According to Pereira et al. (2013), colour is a quality criterion used as a procedure check during food processing operations such as roasting and baking. It influences consumer cravings and market performance of a food product (Adeyemo et al. 2022). Thus, the panelists preference for the crust and crumb colours of the control cookie WC100 (7.73 and 7.33, respectively) which were significantly higher ($P \leq 0.05$) than those (5.60–6.60 and 5.27–6.40, respectively) of the composite cookies may be due to consumers' familiarity with the conventional golden-brown colour of cookies as compared to the deep-brown/burnt appearance of the composite cookies. The deep-brown colours of the composite cookies may be due to the higher protein and lower carbohydrate contents of their flours which resulted in decreased caramelization during baking, thereby resulting in deep-brown colour. In addition, higher protein content may have contributed by causing more intense Maillard browning in the composite cookies (Deora et al. 2015). Despite this, the relatively high scores for crust and crumb colours of the composite cookies may suggest that the panelists still had significant cravings for these cookies. This may indicate potential optimal market performance for the composite cookies. Composite cookies containing 55–65% CBF were rated significantly higher (6.40–6.73) ($P \leq 0.05$) than the control cookie (6.39) in terms of flavour. This is contrary to the observations of Gernah and Anyam (2014) who reported that inclusion of defatted sesame flour (at levels of 10–30%) negatively affected the aroma of wheat:defatted sesame cookies due to its strong nutty smell. This may be attributed to smaller amount of defatted sesame flour (5%) used in the present study. Furthermore, the additive effect of the natural sweetness of banana which may have significantly contributed its sweet banana flavour to the cookies during baking and possibly masking the nutty taste of sesame flour may be responsible for the panelists' preference for flavor of samples CBC55, CBC60 and CBC65. In addition, the possible conversion of banana starch to sugars during baking would have further sweetened the composite cookies. This might have also influenced the highest rating in terms of aftertaste for composite cookies having the largest amount (65%) of CBF. Although the control cookie had significantly higher ($P \leq 0.05$) score (7.33) for texture than the composite cookies (5.87–6.89), this was closely followed by sample CBC65 (6.89). Consumer acceptability of foods has been reported to be significantly influenced by taste and texture (Piqueras-Fiszman & Spence 2015). However, in this present study, taste (as indicated by flavour and aftertaste) seemed to have had the most significant influence on the panelists' choice of the overall best cookies as shown by the highest rating of overall acceptability for sample CBC65. Hence, this sample was adjudged to be the most acceptable in comparison to other composite and the control wheat cookies. Thus, the composite blend CBF65 with 30% sorghum flour, 65% Cardaba banana flour and 5% defatted sorghum meal may be the best blending ratio for production of organoleptically acceptable gluten-free sorghum:Cardaba banana:defatted sesame cookies comparable with the conventional wheat cookies.

Conclusion

The present study has established the feasibility of preparing acceptable gluten-free cookies with higher nutritional profile and dietary fibre composition as compared to 100% wheat cookies from sorghum-Cardaba banana-defatted sesame seed flour blends. Dietary fibre and mineral element composition followed a dose-dependent trend with higher CBF amount in the formulated cookies resulting in higher values. Addition of CBF significantly improved the functional properties and may have played the most significant role in enhancing the cookie-making potential of sorghum flour. The composite cookies exhibited good physical and acceptable sensorial properties, with composite cookie CBC65 (i.e., 35:65:5 SF:CBF:SM) having the highest flavor, aftertaste and overall acceptability scores as compared to the control cookie and other composite cookies. This may give impetus for proposing these cookies for pilot scale production. The present study has provided significant data relevant for the adoption of composite cookies from sorghum-Cardaba banana-defatted sesame seed meal blends as a potential low-cost, protein-rich high-fibre gluten-free snacks that could serve as functional dietary food supplements for meeting both nutritional and health benefits of both GF and non-GF consumers. Further in vitro and in vivo studies are required to verify these propositions.

Abbreviations

RDS	Rapidly-digestible starch
GFF	Gluten-free food
SF	Sorghum flour
CBF	Cardaba banana flour
SM	Defatted sesame seed meal
GFD	Gluten-free diet
CD	Celiac disease
DF	Dietary fibre
SDF	Soluble dietary fibre
IDF	Insoluble dietary fibre
TDF	Total dietary fibre
GI	Glycemic index
RS	Resistant starch

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Author's contributions
A-OHN conceptualized, designed the experiments and carried out investigations with the assistance of Oguntuase, S.O. who assisted in the chemical analyses. A-OHN collected and analyzed data; wrote, reviewed, edited and approved the final manuscript for submission.

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Availability of data and materials
The dataset used and/or analyzed during this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The Ethical Committee for Human and Laboratory Animals of School of Agriculture and Agricultural Technology, Akure, Nigeria approved the study protocol with reference number FUTA/SAAT/04-2021/031. The experimental design was conducted in accordance with the force laws and regulations as regards both human and animal use and care as contained in the Canadian Council on Animal Care Guidelines and Protocol Review (Canadian Council on Animal Care 1993).

Consent for publication
Not applicable.

Competing interests
The author declares that there are no known competing financial interests.

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References

AACC (2000). *Approved methods of the American Association of Cereal Chemists*, (vol. 1). American Association of Cereal Chemists (AACC) Approved Methods Committee. American Association of Cereal Chemists. https://www.cerealsgrains.org/resources/methods.

Adebo, O. A. (2020). African sorghum-based fermented foods: Past, current and future prospects. *Nutrients*, *12*(4), 1111. https://doi.org/10.3390/nu12041111.

Adegbaju, O. D., Otunola, G. A., & Afolayan, J. A. (2021). *Suitability of fruits and vegetables for provision of daily requirement of dietary fiber targets*. IntechOpen. https://doi.org/10.5772/intechopen.99689.

Adeola, A.A., & Ohizua, E.R. (2018). Physical, chemical, and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea, and sweet potato. *Food Science and Nutrition*, *6*: 532–540. https://doi.org/10.1002/fsn3.590.

Adeyemo, A.E., Omoba, O.S., Olagunju, A.I., & Josiah, S.S. (2022). Chemical composition, in vitro antioxidant properties, and phenolic profile of shallot (Allium ascalonicum L.)-enriched plantain biscuit. *Bulletin of the National Research Centre*, *46*:85. https://doi.org/10.1186/s42269-022-00769-1.

Agama-Acevedo, E., Islas-Hernández, J.J., Pacheco-Vargas, G., Osorio-Díaz, P., & Bello-Pérez, L.A. (2012). Starch digestibility and glycemic index of cookies partially substituted with unripe banana flour. LWT - *Food Science and Technology*, *46*: 177–182. https://doi.org/10.1016/j.lwt.2011.10.010.

Ahure, D., & Ejoha, P.O. (2020). Quality Evaluation of Cookies from Malted Sorghum (Sorghum bicolor), Sprouted Soybean (Glycine max) and Carrot (Daucus carota) Flour Blends. *Asian Journal of Biotechnology and Bioresource Technology*, *6*(1): 14–27.

Alcântara, R. G. D., Fukumasu, H., Raspantini, P. C. F., Raspantini, L. E. R., Steel, C. J., Oliveira, L. D. C., … Vanin, F. M. (2020). Baking effect on resistant starch digestion from composite bread produced with partial wheat flour substitution. *Journal of Food Quality*, *2020*, 9245035, 13 pages. https://doi.org/10.1155/2020/9245035.

Altan, A., McCarthy, K. L., & Maskan, M. (2009). Effect of extrusion cooking on functional properties and *in vitro* starch digestibility of barley–based extrudates from fruit. *Journal of Food Science*, *74*, 77–86.

Anilakumar, K. R., Pal, A., Khanum, F., & Bawa, A. S. (2010). Nutritional, medicinal and industrial uses of sesame (*Sesamum indicum* L.) seeds- An overview. *Agriculturae Conspectus Scientificus*, *75*(4), 159–168.

AOAC (2005). *Official methods of analysis*, (18th ed.,). Association of Official Analytical Chemists.

AOAC. (2012). Official methods of analysis (121–130) 19th edn. Association of Official Analytical Chemists.

Aparicio-Saguilán, A., Sáyago-Ayerdi, S. G., Vargas-Torres, A., Tovar, J., Ascencio-Otero, T. E., & Bello-Pérez, L. A. (2006). Slowly-digestible cookies prepared from resistant starch-rich lintnerized banana starch. *Journal of Food Composition and Analysis*, *20*, 175–181.

Asif-Ul-Alam, S. M., Islam, M. Z., Hoque, M. M., & Monalis, K. (2014). Effect of drying on the physicochemical and functional properties of green banana (*Musa sapientum*) flour and development of baked product. *American Journal of Food Science and Technology*, *2*, 128–133. https://doi.org/10.12691/ajfst-2-4-4.

Awika, J. M. (2017). Sorghum: Its unique nutritional and health-promoting attributes. In J. R. N. Taylor, & J. M. Awika (Eds.), *Gluten-free ancient grains*, (pp. 21–54). Woodhead Publishing.

Awuchi, C. G., Igwe, V. S., & Echeta, C. K. (2019). The functional properties of foods and flours. *International Journal of Advanced Academic Research, Sciences, Technology and Engineering*, *5*(11), 139–160.

Ayo-Omogie, H. N. (2021). Gluten-reduced sweet potato-wheat bread: Influence of fermented sweet potato flour addition on bread quality and dough rheology. *Journal of Culinary Science and Technology*, *19*(3), 187–213. https://doi.org/10.1080/15428052.2020.1738297.

Ayo-Omogie, H. N., Adeyemi, I. A., & Otunola, E. T. (2010). Effect of ripening on some physicochemical properties of cooking banana (*Musa* ABB Cardaba) pulp and flour. *International Journal of Food Science and Technology*, *45*(12), 2605–2611.

Ayo-Omogie, H. N., Jolayemi, O. S., & Chinma, C. E. (2021). Fermentation and blanching as adaptable strategies to improve nutritional and functional properties of unripe Cardaba banana flour. *Journal of Agriculture and Food Research*, *6*, 100214. https://doi.org/10.1016/j.jafr.2021.100214.

Bala, A., Gul, K., & Riar, C. S. (2015). Functional and sensory properties of cookies prepared from wheat four supplemented with cassava and water chestnut fours. *Cogent Food & Agriculture, 1*, 1019815. https://doi.org/10.1080/23311932.2015.1019815

Barrett, E. M., Foster, S. I., & Beck, E. J. (2020). Whole grain and high-fibre grain foods: How do knowledge, perceptions and attitudes affect food choice? *Appetite*, *149*, 104630.

Belmiro, R. H., de Carvalho Oliveira, L., Tribst, A. A. L., & Cristianini, M. (2022). Functional properties of coffee by-products are modified by dynamic high pressure: A case study of clean label ingredient in cookies. *LWT – Food Science and Technology*, *154*, 112601.

Benayad, A., Taghouti, M., Benali, A., Aboussaleh, Y., & Benbrahim, N. (2021). Nutritional and technological assessment of durum wheat-faba bean enriched flours, and sensory quality of developed composite bread. *Saudi Journal of Biological Sciences*, *28*(1), 635–642. https://doi.org/10.1016/j.sjbs.2020.10.053.

Birt, D. F., Boylston, T., Hendrich, S., Jane, J. L., Hollis, J., et al. (2013). Resistant starch: Promise for improving human health. *Advances in Nutrition*, *4*, 587–601.

Calder, P. C., Carr, A. C., Gombart, A. F., & Eggersdorfer, M. (2020). Optimal nutritional status for a well-functioning immune system is an important factor to protect against viral infections. *Nutrients*, *12*, 1181. https://doi.org/10.3390/nu12041181.

Canadian Council on Animal Care (1993). *Guide to the care and use of experimental animals*, (vol. 1, 2nd ed., p. 212).

Cappelli, A., Oliva, N., & Cini, E. (2020). A systematic review of gluten-free dough and bread: Dough rheology, bread characteristics, and improvement strategies. *Applied Sciences*, *10*, 6559. https://doi.org/10.3390/app10186559.

Chauhan, A., Saxena, D. C., & Singh, S. (2016). Physical, textural and sensory characteristics of wheat and amaranth flour blend cookies. *Cogent Food and Agriculture*, *2*, 1125773. https://doi.org/10.1080/23311932.

Chemonics International Inc (2002). *Overview of the Nigerian Sesame Industry*. The United States Agency for International Development (USAID)/ Nigeria RAISE IQC Contract No. PCE-I-00-99-00003-00 Task Order No. 812. USAID PCE-I-00-99-00003-00 November 2002 Task Order No. 812, (p. 34).

Chinma, C. E., Adewuyi, O., & Abu, J. O. (2009). Effect of germination on the chemical, functional and pasting properties of flour from brown and yellow varieties of tiger nut (*Cyperus esculentus*). *Food Research International*, *42*(8), 1004–1009. https://doi.org/10.1016/j.foodres.2009.04.024.

Chinma, C. E., Igbabul, B. D., & Omotayo, O. O. (2012). Quality characteristics of cookies prepared from unripe plantain and defatted sesame flour blends. *American Journal of Food Technology*, *7*(7), 398–408.

Chinma, C. E., Ilowefah, M., Shammugasamy, B., Mohammed, M., & Muhammad, K. (2015). Effect of addition of protein concentrates from natural and yeast fermented rice bran on the rheological and technological properties of wheat bread. *International Journal of Food Science and Technology*, *50*(2), 290–297. https://doi.org/10.1111/ijfs.12619.

Cleary, L., & Brennan, C. (2006). The influence of a (13)(14)-β-D-glucan rich fraction from barley on the physic-chemical properties and in vitro reducing sugars release of durum wheat pasta. *International Journal of Food Science and Technology*, *41*(8), 910–918. https://doi.org/10.1111/j.1365-2621.2005.01141.x.

Cummings, J. H. (2001). The effect of dietary fiber on fecal weight and composition. In *CRC handbook of dietary fiber in human nutrition*, (3rd ed., pp. 183–252). CRC Press.

de Gennaro, G., Difonzo, G., Summo, C., Pasqualone, A., & Caponio, F. (2022). Olive cake powder as functional ingredient to improve the quality of gluten-free breadsticks. *Foods*, *11*, 552. https://doi.org/10.3390/foods11040552.

Demirhan, E., & Özbek, B. (2013). Influence of enzymatic hydrolysis on the functional properties of sesame cake protein. *Chemical Engineering Communications*, *200*(5), 655–666.

Deora, N. S., Deswal, A., & Mishra, H. N. (2015). Functionality of alternative protein in gluten-free product development. *Food Science and Technology International*, *21*(5), 364–379. https://doi.org/10.1177/1082013214538984 PMID: 26048849.

Dhingra, D., Michael, M., Rajput, H., & Patil, R. T. (2012). Dietary fibre in foods: A review. *Journal of Food Science & Technology, 49*, 255–266.

Dossou, S. S. K., Luo, Z., Wang, Z., Zhou, W., Zhou, R., Zhang, Y., … Wang, L. (2022). The dark pigment in the sesame (*Sesamum indicum* L.) seed coat: Isolation, characterization, and its potential precursors. *Frontier in Nutrition*, *9*, 858673. https://doi.org/10.3389/fnut.2022.858673.

Dudu, O. E., Ma, Y., Adelekan, A., Oyedeji, A. B., Oyeyinka, S. A., & Ogungbemi, J. W. (2020). Bread-making potential of heat-moisture treated cassava flour-additive complexes. *LWT-Food Science and Technology*, *130*, 109477. https://doi.org/10.1016/j.lwt.2020.109477.

El-Adawy, T. A. (1997). Effect of sesame seed protein supplementation on the nutritional, physical, chemical and sensory properties of wheat flour bread. *Food Chemistry*, *59*, 7–14.

Englyst, H. N., & Cummings, J. H. (1986). Digestion of the carbohydrates of banana (*Musa paradisiaca sapientum*) in the human small intestine. *The American Journal of Clinical Nutrition*, *44*(1), 42–50.

European Commission (2007). Regulation (EC) No 1924/2006 on nutrition and health claims made on foods. *Official Journal of the European Commission*, *404*, L12/3, L 404/9e25.

Fagbemi, T. N. (1991). Effect of blanching and ripening on functional properties of plantain (*Musa* AAB) flour. *Plant Foods for Human Nutrition*, *54*, 261–269. https://doi.org/10.1023/a:1008153404357.

Falodun, A. I., Ayo-Omogie, H. N., & Awolu, O. O. (2019). Effect of different drying techniques on the resistant starch, bioactive components, physicochemical and pasting properties of Cardaba banana flour. *Acta Universitatis Cibiniensis Series E: Food Technology*, *23*(1), 35–42.

FAO (2003). *Panicum maximum, guinea grass, colonial grass, Tanganyika grass*. Food and Agriculture Organization of the United Nations. http://www.fao.org/ag/aga/agap/frg/AFRIS /DATA/ 118.htm.

Ferrari, A. J., Charlson, F. J., Norman, R. E., Flaxman, A. D., Patten, S. B., Vos, T., & Whitefprd, H. A. (2013). The epidemiological modeling of major depressive disorder: Application for the global burden of disease study 2010. *PLoS One*, *8*(7), e69637. https://doi.org/10.1371/journal.pone.006937.

Galanakis, C. M. (2015). Separation of functional macromolecules and micromolecules: From ultrafiltration to the border of nanofiltration. *Trends in Food Science and Technology*, *42*(1), 44–63. https://doi.org/10.1016/j.tifs.2014.11.005.

Gernah, D. I., & Anyam, K. (2014). Production and quality assessment of protein–rich biscuits from blends of wheat and defatted sesame flours. *International Journal of Food Processing Technology*, *1*, 27–31.

Gumul, D., Ziobro, R., Korus, J., & Kruczek, M. (2021). Apple pomace as a source of bioactive polyphenol compounds in gluten-free breads. *Antioxidants (Basel)*, *10*(5), 807. https://doi.org/10.3390/antiox10050807 PMID: 34069723; PMCID: PMC8161145.

Hager, A. S., Wolter, A., Czerny, M., Bez, J., Zannini, E., Arendt, E. K., & Czerny, M. (2012). Investigation of product quality, sensory profile and ultrastructure of breads made from a range of commercial gluten-free flours compared to their wheat counterparts. *European Food Research and Technology*, *235*(2), 333–344. https://doi.org/10.1007/s00217-012-1763-2.

Haruna, S. A., Akanya, H. O., Adejumo, B. A., Chinma, C. E., & Okolo, C. (2019). The effect of drying temperature on functional/baking properties of flour produced from fresh Orange-Fleshed Sweet Potato Tubers (OFSPT). *American Journal of Engineering Research*, *8*(3), 215–220.

Ho, Y. H., Tan, M., & Seow-Choen, F. (2000). Micronized purified flavonidic fraction compared favorably with rubber band ligation and fiber alone in the management of bleeding hemorrhoids: Randomized controlled trial. *Diseases of the Colon and Rectum*, *43*, 66–69.

Houben, A., Höchstötter, A., & Becker, T. (2012). Possibilities to increase the quality in glutenfree bread production: An overview. *European Food Research and Technology*, *235*, 195–208. https://doi.org/10.1007/s00217-012-1720-0.

Hua, M., Lu, J., Qu, D., Liu, C., Zhang, L., Li, S., et al. (2019). Structure, physicochemical properties and adsorption function of insoluble dietary fibres from ginseng residue: A potential functional ingredient. *Food Chemistry*, *286*, 522–529. https://doi.org/10.1016/j.foodchem.2019.01.114.

Hui, Y. H. (1996). *Edible oil and fat products: General applications*. Wiley.

Hutton, C. W., & Campbell, A. M. (1981). Protein functionality in foods: Water and oil absorption. *American Association of Chemical Society Symposium Series*, *147*, 177–200.

Iwe, M. O., Onyeukwu, U., & Agiriga, A. N. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food & Agriculture*, *2*, 1142409. https://doi.org/10.1080/23311932.2016.1142409.

Jan, N., Naik, H. R., Gani, G., Bashir, O., Amin, T., Wani, S. M., & Sofi, S. A. (2022). Influence of replacement of wheat flour by rice flour on rheo-structural changes, in vitro starch digestibility and consumer acceptability of low-gluten pretzels. *Food Production, Processing and Nutrition*, *4*(9). https://doi.org/10.1186/s43014-022-00088-y.

Juárez-García, E., Agama-Acevedo, E., Sáyago-Ayerdi, S. G., Rodríguez-Ambriz, S. L., & Bello-Pérez, L. A. (2006). Composition, digestibility and application in breadmaking of banana flour. *Plant Food for Human Nutrition*, *61*, 131–137.

Kambabazi, M.-R., Okoth, M. W., Ngala, S., Njue, L., & Vasanthakaalam, H. (2022). Physicochemical properties and sensory evaluation of a bean-based composite soup flour. *Legume Science*, e139. https://doi.org/10.1002/leg3.139.

Kaushal, P., Kumar, V., & Sharma, H. K. (2012). Comparative study of physicochemical, functional, anti-nutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*), pigeon pea (*Cajanus cajan*) flour and their blends. *LWT- Food Science and Technology*, *48*, 59–68.

Kim, J. H., Seo, W. D., Lee, S. K., Lee, Y. B., Park, C. H., Ryu, H. W., & Lee, J. H. (2014). Comparative assessment of compositional components, antioxidant effects, and lignan extractions from Korean white and black sesame (*Sesamum indicum* L.) seeds for different crop years. *Journal of Functional Foods*, *7*, 495–505.

Kim, M.-H., & Choi, M.-K. (2013). Seven dietary minerals (Ca, P, Mg, Fe, Zn, Cu, and Mn) and their relationship with blood pressure and blood lipids in healthy adults with self-selected diet. *Biological Trace Element Research*, *153*, 69–75. https://doi.org/10.1007/s12011-013-9656-1.

Kotsiou, K., Sacharidis, D. D., Matsakidou, A., Biliaderis, C. G., & Lazaridou, A. (2022). Physicochemical and functional aspects of composite wheat-roasted chickpea flours in relation to dough rheology, bread quality and staling phenomena. *Food Hydrocolloids*, *124*, 107322.

Lee, N. K., Sowa, H., Hinoi, E., Ferron, M., Ahn, J. D., Confavreux, C., … Karsenty, G. (2007). Endocrine regulation of energy metabolism by the skeleton. *Cell*, *130*(3), 456–469.

Lin, S., Jin, X., Gao, J., Qiu, Z., Ying, J., Wang, Y., … Zhou, W. (2021). Impact of wheat bran micronization on dough properties and bread quality: Part I - Bran functionality and dough properties. *Food Chemistry*, *353*, 129407. https://doi.org/10.1016/j.foodchem.2021.129407.

Mabhaudhi, T., O'Reilly, P., Walker, S., & Mwale, S. (2016). Opportunities for underutilized crops in southern Africa's post-2015 development agenda. *Sustainability*, *8*, 302.

Maggini, S., Pierre, A., & Calder, P. C. (2018). Immune function and micronutrient requirements change over the life course. *Nutrients*, *10*, 1531. https://doi.org/10.3390/nu10101531.

Maluf, S. W., Wilhelm Filho, D., Parisotto, E. B., Medeiros, G.d. S.d., Pereira, C. H. J., Maraslis, F. T., et al. (2020). DNA damage, oxidative stress and inflammation in children with celiac disease. *Genetics and Molecular Biology*, *43*. https://doi.org/10.1590/1678-4685-gmb-2018-0390.

Man, S., Paucean, A., & Muste, S. (2014). Preparation and quality evaluation of gluten-free biscuits. *Bulletin UASVM Food Science and Technology*, *71*, 38–44. https://doi.org/10.15835/buasvmcn-fst:10080.

Manini, P., Panzella, L., Eidenberger, T., Giarra, A., Cerruti, P., Trifuoggi, M., & Napolitáno, A. (2016). Efficient binding of heavy metals by black sesame pigment: Toward innovative dietary strategies to prevent bioaccumulation. *Journal of Agricultural and Food Chemistry*, *64*, 890–897. https://doi.org/10.1021/acs.jafc.5b05191.

Marcel, N. R., Patrick, Y., Seraphine, E., & Robert, N. (2021). Utilization of over-ripe banana/ plantain-maize composite flours for making doughnuts: Physicochemical, functional, rheological, and sensory characterization. *Journal of Food Measurement and Characterization*, *15*, 59–70. https://doi.org/10.1007/s11694-020-00609-8.

Mohammed, I., Ahmed, A. R., & Senge, B. (2012). Dough rheology and bread quality of wheat–chickpea flour blends. *Industrial Crops and Products*, *36*(1), 196–202. https://doi.org/10.1016/j.indcrop.2011.09.006.

Mulla, M. Z., Subramanian, P., & Dar, B. N. (2022). Functionalization of legume proteins using high pressure processing: Effect on technofunctional properties and digestibility of legume proteins. *LWT - Food Science and Technology*, *158*, 113106. https://doi.org/10.1016/j.lwt.2022.113106.

Namiki, M. (1995). The chemistry and physiological functions of sesame. *Food Reviews International*, *11*(2), 281–329. https://doi.org/10.1080/87559129509541043.

Nevara, G. A., Muhammad, S. K. S., Zawawi, N., Mustapha, N. A., & Karim, R. (2021). Dietary fiber: Fractionation, characterization and potential sources from defatted oilseeds. *Foods*, *10*, 754. https://doi.org/10.3390/foods10040754.

Obeidat, B. A., Abdul-Hussain, S. S., & Al-Omari, D. Z. (2012). Effect of addition of germinated lupine flour on the physiochemical and organoleptic properties of cookies. *Journal of Food Processing and Preservation*, *37*(5), 637–643. https://doi.org/10.1111/j.1745-4549.2012.00688.x.

Odenigbo, M. A., Asumugha, V. U., Ubbor, S., Nwauzor, C., Otuonye, A. C., Offia-Olua, I. B. I., … Anozie, G. O. (2013). Proximate composition and consumption pattern of plantain and cooking-banana. *British Journal of Applied Science and Technology*, *3*(4), 1035–1043.

Ogundele, O. M., Ojedokun, F. O., Fasogbon, B. M., & Bamidele, O. P. (2022). Effects of roasted defatted sesame seed (*Sesamum indicum*) flour addition on the nutritional quality, dietary fibre, and glycaemic index of malted amaranth grain (*Amaranthus hybridus*) flour. *Food Research*, *6*(6), 78–87.

Ogunsakin, O. A., Banwo, K., Ogunremi, O. R., & Sanni, A. I. (2015). Microbiological and physicochemical properties of sourdough bread from sorghum flour. *International Food Research Journal*, *22*(6), 2610–2618.

Ojo, M. O., Ariahu, C. C., & Chinma, E. C. (2017). Proximate, functional and pasting properties of cassava starch and mushroom (*Pleurotus pulmonarius*) flour blends. *American Journal of Food Science and Technology*, *5*, 11–18. https://doi.org/10.12691/AJFST-5-1-3.

Olorode, O. O., & Sobowale, S. S. (2021). Evaluation of qualities of extruded snacks from yellow cassava flour substituted with processed sesame seed flour. *World Journal of Advanced Research and Reviews*, *10*(01), 074–086.

Oluwalana, I. B., Ogunsua, A. O., & Abiose, S. H. (2005). Controlling ripening in mature green plantain (*Musa* AAB) by irradiation and plastic film packaging. *Journal of Applied Tropical Agriculture*, *10*(1), 54.

Omoba, O. S., & Omogbemile, A. (2013). Physicochemical properties of sorghum biscuits enriched with defatted soy flour. *British Journal of Applied Science and Technology*, *3*(4), 1246–1256. https://doi.org/10.9734/BJAST/2013/4191.

Omoba, O. S., Taylor, J. R. N., & de Kock, H. L. (2015). Sensory and nutritive profiles of biscuits from whole grain sorghum and pearl millet plus soya flour with and without sourdough fermentation. *International Journal of Food Science and Technology*, *50*, 2554–2561. https://doi.org/10.1111/ijfs.12923.

Omowaye-Taiwo, O. A., Fagbemi, T. N., Ogunbusola, E. M., & Badejo, A. A. (2015). Effect of germination and fermentation on the proximate composition and functional properties of full-fat and defatted *Cucumeropsis mannii* seed flours. *Journal of Food Science and Technology*, *52*(8), 5257–5263. https://doi.org/10.1007/s13197-014-1569-2.

Onsaard, E. (2012). Sesame proteins. *International Food Research Journal*, *19*(4), 1287–1295.

Onyango, C., Mutungi, C., Unbehend, G., & Lindhauer, M. G. (2011). Modification of gluten-free sorghum batter and bread using maize, potato, cassava or rice starch. *LWT - Food Science and Technology*, *44*, 681–686. https://doi.org/10.1016/j.lwt.2010.09.006.

Osundahunsi, O. F. (2009). Scanning electron microscope study and pasting properties of ripe and unripe plantain. *Journal of Food, Agriculture and Environment*, *7*(3–4), 182–186.

Ovando-Martinez, M., Syago-Ayerbi, S., Agama-Acevedo, E., Goñi, I., & Bello-Perez, L. A. (2009). Unripe banana flour as an ingredient to increase the indigestible carbohydrate of pasta. *Food Chemistry*, *113*, 121–126. https://doi.org/10.1016/j.foodchem.2008.07.035.

Panzella, L., Eidenberger, T., Napolitano, A., & D'Ischia, M. (2012). Black sesame pigment: DPPH assay-guided purification, antioxidant/antinitrosating properties, and identification of a degradative structural marker. *Journal*

of Agriculture and Food Chemistry, *60*, 8895–8901. https://doi.org/10.1021/jf2053096.
Pereira, D., Correia, P. M., & Guine, R. P. (2013). Analysis of the physical-chemical and sensorial properties of maria type cookies. *Acta Chimica Slovenica*, *6*, 269–280. https://doi.org/10.2478/acs-2013-0040.
Piqueras-Fiszman, B., & Spence, C. (2015). Sensory expectations based on product-extrinsic food cues: An interdisciplinary review of the empirical evidence and theoretical accounts. *Food Quality and Preference*, *40*, 165–179.
Pontieri, P., & Del Giudice, L. (2016). Sorghum: A novel and healthy food. In *Encyclopedia of food and health*, (pp. 33–43).
Prasad, A. S. (2008). Zinc in human health: Effect of zinc on immune cells. *Molecular Medicine*, *14*, 353–357. https://doi.org/10.2119/2008-00033.
Prasadi, N. V. P., & Joye, I. J. (2020). Dietary fibre from whole grains and their benefits on metabolic health. *Nutrients*, *12*, 3045. https://doi.org/10.3390/nu12103045.
Rai, S., Kaur, A., & Chopra, C. S. (2018). Gluten-free products for celiac susceptible people. *Frontiers in Nutrition*, *5*, 116. https://doi.org/10.3389/fnut.2018.00116.
Rai, S., Kaur, A., & Singh, B. (2014). Quality characteristics of gluten free cookies prepared from different flour combinations. *Journal of Food Science and Technology*, *51*, 785–789. https://doi.org/10.1007/s13197-011-0547-1.
Romero-Díaz, C., Duarte-Montero, D., Gutiérrez-Romero, S. A., & Mendivil, C. O. (2021). Diabetes and bone fragility. *Diabetes Therapy*, *12*, 71–86. https://doi.org/10.1007/s13300-020-00964-1.
Rowicka, G., Czaja-Bulsa, G., Chełchowska, M., Riahi, A., Strucińska, M., Weker, H., & Ambroszkiewicz, J. (2018). Oxidative and antioxidative status of children with celiac disease treated with a gluten free-diet. *Oxidative Medicine and Cellular Longevity*, *2018*, 1324820. https://doi.org/10.1155/2018/1324820.
Ruslan, K., Happyniar, S., & Fidrianny, I. (2018). Antioxidant potential of two varieties of Sesamum indicum L. collected from Indonesia. *Journal of Taibah University Medical Sciences*, *13*(3), 211–218.
Sanni, T. A., Ogunbusola, E. M., Jaiyeoba, C. N., & Araoye, K. T. (2020). Nutritional and sensory characteristics of bread produced from wheat and cassava flour, fortified with sorrel seed protein isolate. *FUOYE Journal of Engineering and Technology*, *5*(1), 6–10.
Schneeman, B. O. (2008). Dietary fibre and gastrointestinal function. In *Advanced dietary fibre technology*, (pp. 168–176). Blackwell Science Ltd..
Schober, T. J., & Bean, S. R. (2008). Sorghum and maize. In E. K. Arendt, & F. D. Bello (Eds.), *Gluten-free cereal products and beverages*, (pp. 101–118). Elsevier.
Sobowale, S. S., Adebo, O. A., & Mulaba-Bafubiandi, A. F. (2019). Production of extrudate pasta from optimal-sorghum-peanut flour blend and influence of composite flours on some quality characteristics and sorption isotherms. *Transactions of the Royal Society of South Africa*, *74*, 268–275.
Soliman, G. A. (2019). Dietary fiber, atherosclerosis, and cardiovascular disease. *Nutrients*, *11*, 1155.
Suitor, C.W., & Murphy, S.P. (2013). Chapter 13—Nutrition guidelines to maintain health. In: Coulston AM, Boushey CJ, Ferruzzi MG (eds) Nutrition in the prevention and treatment of disease 3rd edn. Academic press, Massachusetts, USA, 231–247. https://doi.org/10.1016/B978-0-12-391884-0.00013-5.
Suresh, C., & Samsher, S. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, *8*(38), 4849–4852. https://doi.org/10.5897/AJAR2013.6905.
Sze-Tao, K. W., & Sathe, S. K. (2000). Functional properties and in vitro digestibility of almond (*Prunus dulcis* L.) protein isolate. *Food Chemistry*, *69*, 153–160. https://doi.org/10.1016/S0308-8146(99)00244-7.
Taylor, J. R. N., & Emmambux, M. N. (2018). Gluten-free cereal products and beverages. In E. K. Arendt, & F. D. Bello (Eds.), *Gluten-free foods and beverages from millets*, (pp. 119–148). Elsevier.
Topping, D. L., & Clifton, P. M. (2001). Short-chain fatty acids and human colonic function: Roles of resistant starch and non-starch polysaccharides. *Physiological Reviews*, *81*, 1032–1054.
Trinidad, P. T., Mallillin, A. C., Loyola, A. S., Sagum, R. S., & Encabo, R. R. (2010). The potential health benefits of legumes as a good source of dietary fibre. *British Journal of Nutrition*, *103*, 567–574.
Tsatsaragkou, K., Gounaropoulos, G., & Mandala, I. (2014). Development of gluten free bread containing carob flour and resistant starch. *LWT - Food Science and Technology*, *58*(1), 124–129. https://doi.org/10.1016/j.lwt.2014.02.043.
Tsatsaragkou, K., Protonotariou, S., & Mandala, I. (2016). Structural role of fibre addition to increase knowledge of non-gluten bread. *Journal of Cereal Science*, *67*, 58–67. https://doi.org/10.1016/j.jcs.2015.10.003.
Ubbor, S. C., Ekeh, J. I., Agwo, O. E., Iguh, B. N., & Egwu, S. N. (2022). Physico-chemical and sensory properties of cookies produced from composite flour of wheat, *acha* and whole Orange-Fleshed Sweet Potato. *Nigerian Agricultural Journal*, *53*(1), 248–259.
Umbur, W. A., Terhemba, I. T., Olaitan, I. N., Ukwenya, I. S., Aondohemba, U. V., Nguemo, K. D., … Audu, O. M. (2021). Nutrient composition of wheat-defatted sesame bread. *International Journal of Food Science and Nutrition Diet*, *10*(5), 552–557.
USDA (2022). *Grain and feed update*. United States Department of Agriculture. Foreign Agricultural Service Report number: NI2022-0008. Date uploaded October 24, 2022. Date assessed: February 2, 2023.
Wang, K., Lu, F., Li, Z., Zhao, L., & Han, C. (2017). Recent developments in gluten-free bread baking approaches: A review. *Food Science and Technology: Campinas*, *37*(Suppl. 1), 1–9. https://doi.org/10.1590/1678-457X.01417.
Weyh, C., Krüger, K., Peeling, P., & Castell, L. (2022). The role of minerals in the optimal functioning of the immune system. *Nutrients*, *14*, 644. https://doi.org/10.3390/nu14030644.
WHO/FAO Consultation (2003). *Diet, nutrition and the prevention of chronic diseases. Report of a Joint WHO/FAO Expert Consultation, WHO technical report series 916*. World Health Organization.
Witczak, M., Ziobro, R., Juszczak, L., & Korus, J. (2016). Starch and starch derivatives in gluten-free systems - A review. *Journal of Cereal Science*, *67*, 46–57. https://doi.org/10.1016/j.jcs.2015.07.007.
Yang, Y., Wang, J., Zhang, Y., Li, J., & Sun, W. (2018). Black sesame seeds ethanol extract ameliorates hepatic lipid accumulation, oxidative stress, and insulin resistance in fructose-induced nonalcoholic fatty liver disease. *Journal of Agriculture and Food Chemistry*, *66*, 10458–10469. https://doi.org/10.1021/acs.jafc.8b04210.
Zebib, H., Bultosa, G., & Abera, S. (2015). Physico-chemical properties of sesame (*Sesamum indicum* L.) varieties grown in northern area, Ethiopia. *Agricultural Sciences*, *6*(02), 238.
Ziobro, R., Juszczak, L., Witczak, M., & Korus, J. (2016). Non-gluten proteins as structure forming agents in gluten free bread. *Journal of Food Science and Technology*, *53*, 571–580.

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