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Functional and Physicochemical Properties of Flour and Cookies from Wheat Soybean and Orange Fleshed Potatoes Blend

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Authors' contributions

This work was carried out in collaboration among all authors. Author OPG designed the study, carried out all laboratories analysis, performed the statistical analysis and wrote the first draft of the manuscript. Authors OEM and TAEM approved the design of the study, supervised the study and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The incorporation of nutritionally-rich yet underutilized local crops into popularly consumed cookies could be employed to address undernourishment in snacking. Hence, the feasibility of producing cookies from wheat flour, soybean and orange fleshed sweet potatoes (OFSP) was investigated. A completely randomized design (CRD) was used in the experiment. A total of 5 samples of composite flour in varying proportions of 100:0:0, 75:20:5, 70:20:10, 65:20:15, 60:20:20 were used

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for the production of cookies. The cookies were subjected to functional, proximate, antinutrient and physical analyses using standard laboratory procedures. The functional properties of the flour increased in addition of soybean and OFSP flour respectively. Results from the proximate composition (%) of the flour samples showed that protein, ash, fat, crude fibre, moisture and carbohydrate ranged from (10.54 - 11.39), (1.61 - 2.95), (1.60 - 3.30), (1.25 - 3.38), (10.77 - 14.36) and (65.99 - 74.22) respectively. The antinutrients analysed for the flour and cookies samples were in ranges of (4.81 - 11.87 mg/100g) (0.52 – 1.64 mg/100g), (11.71 – 19.03 mg/100g) (5.89 – 7.07 mg/100g), (6.87 – 10.73 TIU/g) (0.99 – 1.66 TIU/g) and (7.35 - 12.67 mg/100g) (0.92 – 1.22 mg/100g) for oxalate, tannin, trypsin inhibitor and phytate respectively. The minerals (iron and zinc) were bioavailable in the cookies and the effect of phytate could not hinder their bioavailability. The physical properties (weight, diameter and thickness) of the cookies substituted with constant 20% soybean in combination with variations of OFSP increased significantly ($p < 0.05$) except the spread ratio. This study suggests that incorporation of soybean and OFSP flour into wheat flour will improve the nutritional quality of cookies mostly consumed by the populace.

Keywords: Functional; proximate; mineral; antinutritional; molar ratio; soybean; orange-fleshed sweet potatoes; wheat.

1. INTRODUCTION

“Snacks including cookies are widely consumed all over the world” [1]. “They represent an important part of the human diet, especially as a source of energy and may be consumed in between meals. The consumption of cereal snacks such as biscuits, cookies, wafers and shortbread has become very popular in Nigeria especially among children of which cookies are one of the most consumed cereal foods apart from bread because they are readily available in local shops as ready to eat, cheap, convenient and appetizing food products” [2,3] observed that “carbohydrates and added sugars tend to be over-consumed during snacking. They opined that replacement of current snack choices with nutrient-dense foods could lower the risks of nutrient deficiencies and excess nutrient consumption which can be obtained from a composite flour”. “Composite flour is a mixture of varying proportion of two or more flour used for production of bread, pastries, cake and other confectionery products that are conventionally produced from wheat flour to increase the essential nutrients in human diet and increase the economic relevance of indigenous crops” [4].

According to [5], “composite flour are potential gateway to stimulate and scale up the consumption of underutilized crops such as orange sweet fleshed potatoes (OFSP) or neglected crops. Cookies with high sensory ratings have been produced from blends of malted barley/wheat, wheat/jackfruit seed and other products. Wheat (*Triticum aestivum L.*) has been used since time immemorial for the manufacture of several bakery products because of the presence of unique gluten protein which is responsible for providing the viscoelastic characteristics to dough”. Kumar [6] discovered that “in wheat products such as bread, gluten network formation is desirable for gas retention and better volume of product, while in products such as biscuits and cookies, extensibility is required, so gluten formation is undesirable”. “Due to the limited amount of wheat produced in Nigeria and cost of importation, the government has collaborated with research institutes to encourage the use of composite flour in the production of bread and related food products such as cookies” [7]. “Soybean (*Glycine max*) is an edible legume highly famed for being nutritious” [8]. “As they contain a high amount of protein, essential vitamins, minerals, complex carbohydrates, and dietary fibre” [9]. “Soybeans also contain phytochemicals that contribute to the health of the human body” [10]. “OFSP serve as a cheap and sustainable source of Pro-Vitamin A, especially for vulnerable populations. OFSP is a special type of biofortified sweet potato that contains 76kcal energy, 1.37g protein, 2.5g fibre, 0.72mg iron, 0.2mg zinc, 588 mg RAE of vitamin A and 12.8g of vitamin C”. [11]. “It appears that there is a growing demand and interest for OFSP because it is a good source of beta-carotene, the major precursor of vitamin A. Depending on the variety, the beta-carotene content in OFSP may vary between 5091 µg/100 g and 16,456 µg/100 g” [12]. “OFSP has been suggested to have great potential to be used in food-based programs to address vitamin A deficiency” [13,7] observed that “in Nigeria, the reliance on wheat flour by baking industries has over the years restricted the use of other cereals, tuber and oilseed crops available for domestic use. Cookies are grossly nutritionally inadequate as they consist mainly of un-supplemented cereals deficient in Pro-Vitamin A and other essential amino acids such as lysine, threonine and tryptophan which are necessary for proper growth and development". OFSP and soybean which are valuable sources of vitamin A carotenoids, antioxidants, minerals, proteins, fats, dietary fibre etc., could be exploited in the production of cookies. The nutritional content of cookies is expected to improve as a result of addition of Pro-vitamin A carotenoids from OFSP flour and minerals, proteins, and fat from soybean flour. Formulating complementary food with wheat, soybean and OFSP flour could not only improve the nutrient composition of the complementary food but also reduce post-harvest losses of these locally grown food items. The thrust of this study therefore is to improve the nutritional content of cookies through fortification of composite flours obtained from underutilized crops such as OFSP and soybeans.

2. MATERIAL AND METHODS

2.1 Materials and Sample Collection

Dangote wheat flour, Dangote granulated sugar, Peak powdered milk, topper baking fat, Dangote salt and Longman baking powder were procured from Wuse market, Abuja FCT, Nigeria. Soybean seeds and orange-fleshed sweet potato tubers were obtained from Gosa market, airport road, Abuja FCT, Nigeria. The chemicals used were of analytical grade.

2.2 Preparation of Soybean Flour

The method described by Shiriki [14] was employed. The soybeans were sorted and washed with clean water. The seeds were then soaked overnight in cold water for 12 h at 30 °C and de-hulled. It was then boiled at 100 °C for 30 min. The seeds were drained through a nylon sieve for 1 h. The seeds were oven-dried at 60 °C for 30 min, milled and sieved using 0.5 mm mesh. The flour was stored in low-density dark-coloured polythene bags stored in plastic containers with airtight lids at room temperature (30±2°C) until analysis.

2.3 Preparation of OFSP Flour

The orange flesh sweet potato flour was produced using the method described by Kudadam [15]. The sweet potato tubers were peeled and cut into thin pieces manually. The potato slices were then soaked for 30 min to prevent browning reactions. The OFSP slices were oven dried at 60 °C till constant weight and milled into flour using the laboratory grinder. The flour was then passed through 0.5 mm mesh sieve, packed in airtight containers and stored in the refrigerator till further use.

2.4 Research Design

The research design is Completely Randomized design (CRD). Wheat, soybean and OFSP flours were mixed at five different proportions to give 100g composite.

2.5 Flour Blend Formulation

The composite flour was prepared by replacing wheat flour (WF) with soybean and OFSP flours at the ratios of 100:0:0, 75:20:5, 70:20:10, 65:20:15 and 60:20:20 respectively as shown in Table 1. Sample ratio of 100:0:0 with 100% WF served as a reference sample. The winnowed materials were oven-dried at 60 °C for 30 min and milled with the aid of a Kenwood Chef blender to form fine particle size prior to its use. The wheat, soybean and orange-fleshed sweet potato flours were weighed separately with the aid of a digital electronic weighing balance at different proportions. The formulation was done to enhance the nutrient (particularly protein and Pro-vitamin A) content of the cookies.

2.6 Preparation of Cookies from Composite Flours

The cookies were prepared using the method described by [16]. The essential ingredients for the production of cookies in their various proportions were weighed in. Sweeteners (sucralose and shortening were creamed for 10mins until light and fluffy. Egg and flour were added to the mixture followed by milk, salt and baking powder using a Kenwood hand mixer. The mixture was thoroughly kneaded into consistent dough for about 30 min and allowed to rest. The dough was rolled on flat wooden surface sprinkled with flour to form a uniform thickness and cut into predetermined size and shape using a biscuit cutter. The dough was arranged in greased trays and baked in a preheated oven operating at 178 ^{o}C for 25 min. The biscuits were allowed to cool down to the room temperature for 5 – 10 min before packaged in polythene bags and stored for evaluation.

Table 1. Formulation of wheat, soybean and orange fleshed sweet potatoes flour blends for cookies production

W:S:OFSP	Wheat Flour	Soybean	OFSP Flour
100:0:0	100	20	00
75:20:5	75	20	5
70:20:10	70	20	10
65:20:15	65	20	15
60:20:20	60	20	20

2.7 Determination of Functional Properties

The parameters of functional properties determined were Oil Absorption Capacity (OAC), Bulk Density (BD), Gelatinization Temperature (GT), Swelling Index (SI) and Water Absorption Capacity (WAC) as described by [17].

2.8 Proximate Analysis

The crude protein content, crude fibre content, moisture content, fat content and ash content of the composite flour were determined in triplicate using established analytical procedures described by [18]. The carbohydrate content was estimated by a difference of 100% after accounting for moisture, protein, fibre, ash, and fat.

2.9 Antinutritional Composition

The tannin, oxalate, trypsin inhibitor and phytate was determined as described by Norhaizan [19].

2.10 Determination of Phytate Mineral Molar Ratio

The moles of phytate and minerals were obtained by dividing the weight of phytate with minerals of each mineral molecular weight as described by Norhaizan [19]. The phytate mineral molar ratio was obtained by dividing the moles of phytate by the moles of each mineral.

2.11 Determination of Physical Properties

The weight, diameter, thickness and spread ration of cookies were determined according to the method described by Dabel [20].

2.12 Statistical Analysis

The experiments were conducted in triplicates and data generated were analysed using analysis of Variance (ANOVA). Means were separated by Duncan multiple range test. A significant difference was accepted at 5 % level of probability ($p < 0.05$) using Statistical package for Social Sciences (SPSS) version 23.

3. RESULTS AND DISCUSSION

3.1 Functional Properties of Wheat, Soybean and OFSP Composite Flour

“Functional properties of flour are important for the selection of crops for use in value-added product development. The swelling index (SI) is the degree of starch from the flour that absorbs water. It is worth noting that swelling capacity (SC) is evidence of non-covalent bonding between molecules within starch granules and also a factor of the ratio of α-amylose and amylopectin ratios. However, the swelling capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations” [21]. The overall values were lower (2.213 - 3.617) than wheat-soy-sweet potato composite flour reported by Okafor [22] who observed that there was a decrease in SC as the level of incorporation of sweet potatoes increased. This observation was also reported by Chandra [21] submitting that the swelling index of composite flours is highly affected by the level of potatoes flour, because potatoes is a rich source of starch. Swelling power of flour granules is an indication of the extent of associative forces within the granule. It depends on sizes of particles, types of variety and processing methods [23]. Lower swelling index observed in samples with 60:20:20 % of W:S:OFSP could be attributed to the increased substitution and fat content of soybean which interferes with starch granules by forming films around the granules and high protein which forms a starch protein complex thus reducing the SC [24]. The 5% OFSP showed a higher SI due to the high content of wheat which has high amylopectin content as observed by Klunklin [25].

Water absorption capacity (WAC) reflects the amount of water that the flour can absorb and retain. The overall values were similar to the values obtained by Culetu [26] for chickpea flour

(1.92 g/g) and teff and amaranth flours (0.95 g/g). However, it was observed that the WAC increased as the proportion of OFSP increased from 5 – 20%. These values were similar to the values (1.57 – 2.01) reported by Kanu [23] for varieties of OFSP breeding lines. This shows that OFSP could enhance the absorption of water during of flour processing into the dough. The high values of WAC can be attributed to the amount and nature of hydrophilic constituents and the nature of the protein. Agreeing to the result of this study, [23] suggests that "the flours from the OFSP would be useful in foods such as bakery products which require hydration to improve handling characteristics". "For an improved food texture of baked products (such as bread, cookies), higher values for water absorption are desired. Higher water absorption values were attributed to the higher content of starch and fibre" [27]. Patil [27] also stated that "higher protein content tends to increase water absorption, therefore, this shows that 60:20:20 exhibited the highest water absorption capacity". [23] reported that "water absorption property indicates the ability of a product to associate with water under conditions when water is limiting such as making of the dough and paste". "The water and oil absorption capacity depend on the type of protein, amino acid composition and protein polarity and hydrophobicity" [28].

The oil absorption capacity (OAC) of the control (100% wheat) had the lowest value. The increase in values obtained for fortified samples were higher than values (1.8 – 1.9 g/g) obtained by Culetu [26] for gluten-free flours such as amaranth, tiger nut, and chickpea flours and values (1.10 - 1.40 g/ml) obtained by Kanu [23] for varieties of OFSP. In their opinion, the oil absorption capacity of flours is important for the development of new food products as well as their storage stability (particularly for flavour binding and in the development of oxidative rancidity). "Both the protein content and type contribute to the oil-retaining properties of food materials. OAC is attributed mainly to the physical entrapment of oils. It is an indication of the rate at which protein binds to fat in food formulations" [29]. "They noted that high OAC flours are suitable for retaining the flavour and enhance the mouthfeel when used in foods. Moreover, variation in the amylose/amylopectin ratio and content of individual flours can contributes to differences in the water as well as oil absorption capacity of flour" [26].

The bulk densities increased (P = .05) significantly in the fortified samples while a reduction in value was observed as the incorporation of OFSP increased from 5% to 20% respectively. The bulk density observed in this study is within the range 0.68 – 0.82 g/cm3 as reported by reported by [30]. Olaitan [31] reported an "increase in bulk density which agrees with this work". "The increase in bulk density could be due to the increased addition of composite flour" [21]. "Nutritionally, low bulk density promotes the digestibility of foods especially in children with immature digestive systems while high bulk density decreases the caloric and nutrient intake of children resulting in growth faltering" [31]. "Low bulk density then implies that the product can easily be packaged for economic use. Moreso, low bulk density has nutritional and economic significance as more of the products can be eaten thus leading to high energy and nutritional density. However, bulk density is a measurement of the porosity of a product which influences the design of the packaging material. Bulk density is affected by the moisture content and the particle sizes of the starch. The differences in the particle size may be the cause of variations in the bulk density of the OFSP. The high bulk density of the sweet potato breeding lines is an indication that they can be used as thickeners" [23].

"The variation in the thermal properties among the different flours are influenced by some factors such as: size of the starch granule, molecular structure of the amylopectin (branch, length and weight), starch, protein and dietary fibre content, as well as the presence of other compounds" [32]. "The gelatinization temperature (GT) of the control (100:0:0) was lower than values obtained from the fortified samples. However, there was a significant (P = .05) temperature increase in the fortified samples. During starch gelatinization, the helix structure and crystallinity of the starch is lost and the granule is disrupted. Albeit, the increase in temperature may be due to the higher fat and fibre content of soybean and sweet potatoes. The swelling of the starch granule is disturbed by the presence of non-starch compounds such as fat, which leads to higher gelatinization temperatures" [33]. Donaldben [34] reported that "gelatinization temperature of the flour samples blends increased with increased addition of OFSP and cashew nut flour. Increasing fibre content appears to delay gelation and subsequently its temperature. Thus, higher heat energy is required to attain significant gelation. They discovered that waxy and regular maize gelatinize at 62 - 72°C, whereas high-amylose

Table 2. Functional properties of wheat, soybean and OFSP composite flour

W:S:OFSP (%)	SI	WAC (g/ml)	OAC (g/g)	BD (g/cm^3)	GT(^{o} C)
100:0:0	1.20^d±0.02	1.31^e±0.04	1.61^d±0.03	0.730^e±0.002	68.0^c±0.0
75:20:5	1.38^a±0.03	1.87^d±0.05	2.32^c±0.08	0.825^a±0.003	73.0^b±1.4
70:20:10	1.35^{ab}±0.00	1.99^c±0.02	2.51^b±0.02	0.793^b±0.003	74.0^{ab}±1.4
65:20:15	1.31^{bc}±0.01	2.10^b±0.00	2.59^b±0.03	0.783^c±0.001	75.5^{ab}±0.7
60:20:20	1.27^c±0.01	2.31^a±0.01	2.75^a±0.01	0.764^d±0.004	76.5^a±0.7

Values are means ± standard deviations of triplicate determinations. Data in the same column bearing different superscripts differ significantly P=.05

starches begin to swell below 100°C, temperatures greater than 130°C are required to fully disperse these starches. This is because more amylose molecules are involved in the crystalline regions of the high amylose starch than in waxy and regular starches". However, [35] submitted that "decrease in gelation capacity is due to the addition of composite flours thus increasing the concentration of protein and enhancing the interaction among the binding forces which in turn increases the gelling ability of the flour". "Gelation properties are related to WACs and takes place at high water protein concentration because of great intermolecular contact during heating" [35]. The formation of gel provides a structural matrix for holding water and other soluble materials like sugar and flavour [36].

3.2 Proximate Composition of Wheat Soybean Orange Fleshed Sweet Potatoes Composite Flour

The MC in samples was observed to increase in the fortified samples as OFSP increased with a constant 20% rate of soybean. There was no significant (*P* = .05) difference between samples with the control (100% wheat) and fortified flours. The values obtained were similar to 10.20 - 12.22% obtained for wheat, soybean moringa leaf composite flours [37] and also in agreement with the research work of [38]. The moisture content values obtained were within the recommended moisture content (10%) for storage stability [39] thus, the sweet potato flour will have a longer shelf life if properly stored under a good condition. "However, the moisture content increased with decrease in the carbohydrate value of the samples enhancing nutritional products, thus implying that the flour can be stored if properly packaged" [40].

The ash content was observed to increase as shown in the results. There was a significant (*P* = .05) difference between the control (100% wheat) and the fortified samples, however the ash content increased as the rate of incorporation increased, a similar trend also observed by [41]. Damian [42] reported lower ash contents values than those of this work. The increase in the ash content was as a result of the OFSP flour. According to [43] the increase in ash content implies that the samples are good sources of minerals. [44] confirmed "the high crude ash contents (4.60 - 7.20%) of OFSP (KJP specie) could be a rich source of mineral salts". "Ash is an inorganic compound present in a food which helps in the breaking down of some organic compounds such as protein, fat and carbohydrates" [39].

The fat content increased (*P* = .05) significantly in the fortified samples but decreased as the rate of incorporation increased. Banigo [45] reported a decrease in fat content when meat balls were produced with increased addition of African yam bean (AYB). The increase in fat was reported in complementary flours due to higher fortification with chickpea [46], a similar legume like soybean. The increased fat content could be due to the composition of AYB and due to its high fat content [47], a similar observation in soybean. The low-fat content obtained in this study agrees with the findings of [48] that sweet potato is low in fat.

There was a significant (*P* =.05) increase in the fibre content in the fortified samples. A similar observation was reported by Verem [37] with values (2.05% - 3.00%) for wheat soybean moringa leaf composite flour. They submitted that the crude fibre content of the flour was enhanced with increase in moringa leaf flour and 20% soybean flour constant. This could be so as soybean, moringa leaf and OFSP are excellent sources of fibre. However, [40] reported "a decrease in fibre with increased addition of soybean and carrot, this study observed an increase due to the addition of OFSP showing the important benefit that fibre can help increase the utilization and absorption of some other micronutrients" [40]. The fibre content was higher in samples with 20% OFSP than other samples.

The protein content of the fortified samples increased significantly (*P* = .05) but decreased as the level of incorporation of OFSP increased. [49] reported an increase in protein when pap and *agidi* jollof were produced by the increased addition of AYB flour in line with this work. The protein values (10.24% - 28.81%) obtained by Verem [37] were similar to the values in this work. They reported that the protein content of flour increased with a decrease in wheat, an increase in moringa leaf and 20% soybean flour constant. According to [50], an increase in protein was observed due to the addition of cowpea which also agrees with this work. This increase in the protein content is due to the increased addition of soybean which is an excellent source of dietary protein. The increase in protein can result in amino acid complementation from soybean to those in the cereal protein [49,40]. Protein is required especially during weaning in order to prevent protein-energy malnutrition [51].

The carbohydrate content significantly (*P* = .05) decreased was in line with [40] who opined that carbohydrate content decreased due to increased substitution of OFSP which agrees with this work. The carbohydrate content was similar to values (67.67 - 44.94%) obtained for wheat soybean moringa leaf composite flour [37]. According to [14] carbohydrate provide heat and energy for all forms of body activity.

3.3 Antinutritional Contents of Wheat, Soybean and Orange Fleshed Sweet Potatoes Composite Flour

There were significant (*P* = .05) differences in the varieties of composite flours examined in Table 4. 20% OFSP had the highest oxalate value. The variations observed might be attributed to the increased rate of incorporation of OFSP. The oxalate values obtained in this study were lower compared to the values reported by Dako [52] for unpeeled OFSP. Oxalate has been reported by Oloniyo [44] "to have a harmful effect on human nutrition and health because it can reduce calcium absorption in the form of calcium oxalate in the blood and thus aid the formation of a kidney stone".

The highest tannin was recorded for 20% OFSP and the least value was observed in the control (100:0:0). The results obtained were lower than values reported by Tiruneh [53]. Dada [54] further reported similar values (0.09 - 0.26 mg/100g) of wheat-AYB-tigernut biscuits. However, the tannin content reduced significantly which could be because of the soaking processing method used. A similar finding was reported by Nzeagwu [55] "for cookies made from tigernut flour. Based on their findings, [54] submitted that tannin inhibits the activities of some enzymes such as trypsin, amylase, and lipase to form insoluble complexes with protein and divalent ions like Fe2+ and Zn thereby reducing their absorption in the body".

The phytate content of the composite flour decreased with the level of incorporation of OFSP where the 75:20:5 had a highest value and the 60:20:20 had a lower value. High values of anti-nutrient (phytate, oxalate and tannin) in food are undesirable because they form complexes with minerals and proteins resulting in its unavailable to the body system [53] thereby leading to carcinogenesis, shock and renal damage. "Anti-nutritional factors are substances that destructively affect the nutritional composition of a food thereby reducing both the mineral and protein bioavailability, digestion and its utilizations in the body" [53].

"The trypsin inhibitor showed a significant (*P* = .05) increase in the fortified flour (6.87 – 10.73 TIU/g) where the 20% OFSP had the lower value of 8.56 TIU/g and 5% had a highest value of 10.73 TIU/g. It was observed that all the molar ratios were below the critical limits (Phy: Ca > 1.56, Phy: Fe > 14 and Phy: Zn > 10)" as reported by Haile [56]. "This implies that the bioavailability of Ca, Fe & Zn are not inhibited by the concentration of phytate in the samples examined. Hence, all the minerals (Ca, Fe and Zn) in the fortified samples will be adequately absorbed by the body when consumed. The molar ratio between phytate and divalent cations (Ca, Fe and Zn) indicates the impact of phytate on the bioavailability (ability of the body to absorb and digest minerals in food after consumption) of dietary minerals and the absorption of these cations were not adversely affected by the amount of phytate in the varieties of sweet potato examined" [53].

3.4 Antinutritional Content of Wheat Soybean Orange Fleshed Sweet Potatoes Cookies

The oxalate content of the fortified cookies had the highest values in sample with 20 % OFSP and the least in sample with 5 % OFSP. Samples containing OFSP had a significant (*P* = .05) increase as the percentage OFSP increased. The tannin content was observed to decrease for all samples where the control sample was observed to have a least tannin value of 5.89 mg/100g. This trend was similar to the values obtained by Dada [54] for biscuit produced from composite flour of wheat, AYB and tiger nut. They opined that the reduction could be due to the soaking method used. Samples containing OFSP had the highest trypsin inhibitor value in sample with 5 % OFSP and the least in sample with 20 % OFSP.

The phytate content of the samples increased for all samples where the control sample recorded a lease phytate value. The values obtained in this study were lower compared to the phytate values reported by Dako [52] "for peeled and unpeeled OFSP (77.75 and 95.15 mg/100g, respectively)". "Phytate produces phytic acid which is a major phosphorous storage component that chelate metallic ion such as Zinc, Calcium and Iron, thereby reducing their bioavailability" [57]. Findings from [58] buttressed that "cookies in the present study were safe to consumers due the processing methods and preparing cookies in the oven decreased the phytate content. Their findings stated that phytic acid decreased during bakery product making due to the action of phytase as well as cooking temperature".

Bioavailability of iron and zinc values show that iron and zinc of the cookies were bioavailable to consumers without the binding effect of phytate. This is due to the molar ratio of phytate: iron values were below the critical value (14) and phytate: zinc values were also below the critical value (10). The measured values of phytate: iron decreased progressively when OFSP amounts were increased; so, the bioavailability of iron is more when OFSP was more in the blended cookies. The measured values of phytate: zinc decreased when the amount of OFSP increased in the developed cookies. This may increase the zinc bioavailability in more OFSP added cookies due to high values of phytate: zinc ratios. Generally, the phytate contents of the composite flour cookies and the molar ratios of phytate: minerals imply that phytate in the cookies of the present study could not impair the bioavailability of iron and zinc to consumers.

3.5 Physical Properties of Wheat, Soybean and Orange Fleshed Sweet Potatoes Cookies

"The mean values of physical characteristics of cookies prepared from composite flour blends of wheat soybean and OFSP are presented in Table 7. The result showed that the physical characteristics of the prepared cookies varied with the variation in the proportion of individual flours in the different blends. Similar observations have been reported by other authors" [59]. The highest weight was observed in samples with 5 % OFSP while 20% OFSP had the least value. The result obtained in this study were lower than 16.62 - 20.14g for rice, unripe banana and sprouted soybean cookies by Inyang [60]. This observation agrees with the reports by Dabel [20]. The recorded lower weight of cookies with 5% OFSP flour addition could be due to the higher fat content of the soybean flour relative to other flours.

The diameter obtained for all samples was similar to the value (3.91 – 4.20) obtained by Inyang [60] for rice, unripe banana and sprouted soybean cookies. The diameter obtained from the study also followed a similar trend as the weight (50.2 - 57.3 mm) for composite wheat flour and malted barley cookies reported by Ikuomola [61]. This could be attributed to the amount of fat added to the flour blends during production. Similarly, an increasing trend for the diameter (38.90 – 40.20 mm) of cookies made from wheat brewers' spent grain flour blends was reported by Gernah [62].

Table 3. Proximate composition of wheat soybean and OFSP composite flour

W:S: OFSP (%)	Moisture	Ash	Fat	Crude fibre	Protein	Carbohydrate
100:0:0	10.54^{d}±0.08	1.61^{e}±0.07	1.60^{d}±0.00	1.25^{d}±0.07	10.77^{e}±0.10	74.22^{a}±0.19
75:20:5	10.72^{c}±0.02	2.42d±0.01	3.30^{a}±0.14	2.67^{c}±0.04	14.36^{a}±0.04	65.99^{e}±0.16
70:20:10	10.85^{c}±0.07	2.60c±0.02	3.10^{ab}±0.14	2.90^{b}±0.02	14.11^{b}±0.04	66.33^{d}±0.09
65:20:15	11.06^{b}±0.03	2.70b±0.00	2.90^{b}±0.00	3.23^{a}±0.09	13.42^{c}±0.09	66.78^{c}±0.01
60:20:20	11.39^{a}±0.03	2.95a±0.01	2.65^{c}±0.07	3.38^{a}±0.04	12.69^{d}±0.05	67.46^{b}±0.10

Values are means ± standard deviations of triplicate determinations. Data in the same column bearing different superscripts differ significantly P=.05

Table 4. Antinutrients concentration of wheat, soybean and OFSP composite flour

W:S:OFSP	Oxalate (mg/100g)	Tannin (mg/100g)	Trypsin inhibitor (TIU/g)	Phytate (mg/100g)
100:0:0	4.81^{e}±0.04	11.71^{e}±0.04	6.87^{d}±0.11	7.35^{e}±0.00
75:20:5	9.96^{d}±0.10	11.92^{d}±0.00	10.73^{a}±0.12	12.67^{a}±0.12
70:20:10	10.73^{c}±0.03	17.31^{c}±0.04	10.49^{a}±0.12	12.08^{b}±0.06
65:20:15	11.21^{b}±0.05	17.91^{b}±0.02	9.36^{b}±0.05	11.76^{c}±0.05
60:20:20	11.87^{a}±0.04	19.03^{a}±0.17	8.56^{c}±0.04	10.71^{d}±0.09

Values are means ± standard deviations of triplicate determinations. Data in the same column bearing different superscripts differ significantly P=.05

Table 5. Antinutrients concentration of the wheat, soybean and orange fleshed sweet potatoes cookies

W:S:OFSP (%)	Oxalate (mg/100g)	Tannin (mg/100g)	Trypsin inhibitor (TIU/g)	Phytate (mg/100g)
100:0:0	0.52^{d}±0.04	5.89^{e}±0.03	0.99^{d}±0.04	0.92^{e}±0.00
75:20:5	1.22^{c}±0.04	8.95^{a}±0.00	2.28^{a}±0.07	1.87^{a}±0.02
70:20:10	1.21^{c}±0.01	8.50^{b}±0.04	2.04^{b}±0.04	1.68^{b}±0.01
65:20:15	1.39^{b}±0.02	7.65^{c}±0.02	1.74^{c}±0.02	1.50^{c}±0.09
60:20:20	1.64^{a}±0.02	7.08^{d}±0.06	1.66^{c}±0.02	1.22^{d}±0.02

Values are means ± standard deviations of triplicate determinations. Data in the same column bearing different superscripts differ significantly P=.05

Table 6. Molar ratio of Phytate/Mineral (bioavailability) of wheat, soybean and OFSP cookies

	Samples (W:S:OFSP)					
Molar Ratio						**Critical Limits**
	100:0:0	75:20:5	70:20:10	65:20:15	60:20:20	
Phy-Ca	0.007	0.0013	0.0011	0.0010	0.0008	>1.56
Phy-Mg	0.0005	0.0010	0.0009	0.0008	0.0006	
Phy-Ph	0.0006	0.001	0.0009	0.0009	0.0007	
Phy-Na	0.0017	0.0025	0.0023	0.0022	0.0019	
Phy-K	0.0003	0.0004	0.0004	0.0004	0.0003	
Phy-Fe	0.032	0.05	0.04	0.03	0.03	>14
Phy=Zn	0.04	0.066	0.055	0.047	0.03	>10

Values are means ± standard deviations of triplicate determinations. Data in the same column bearing different superscripts differ significantly P=.05

Table 7. Physical properties of wheat, soybean and orange fleshed sweet potatoes cookies

W:S:OFSP (%)	Weight (g)	Diameter (cm)	Thickness (cm)	Spread ratio
100:0:0	7.85^{e}±0.01	4.51^{e}±0.02	0.90^{a}±0.00	5.01^{e}±0.02
75:20:5	8.11^{d}±0.01	4.65^{d}±0.04	0.86^{b}±0.01	5.37^{d}±0.00
70:20:10	8.52^{c}±0.02	4.77^{c}±0.03	0.81^{c}±0.01	5.85^{c}±0.01
65:20:15	9.17^{b}±0.01	4.96^{b}±0.08	0.77^{d}±0.01	6.44^{b}±0.01
60:20:20	9.45^{a}±0.01	5.36^{a}±0.02	0.77^{d}±0.01	6.95^{a}±0.09

Values are means ± standard deviations of triplicate determinations. Data in the same column bearing different superscripts differ significantly P=.05

"The thickness obtained for all samples was similar to the results (0.73cm - 0.91cm) obtained for unripe banana and sprouted soybean cookies by Inyang [60]. Variations in cookies' diameter and thickness are reflected in the spread ratio. An increase in thickness could be due to the high adsorption of moisture of the dough with an increase in malted barley bran level, owing to the presence of water-binding components. Moreover, it could also be attributed to the inconsistent rolling thickness of the dough which was exhibited as a result of the addition of high fat content" [61]. A similar finding for thickness was reported by Abdul [63] for cookies produced from blends of wheat flour and oat bran. However, [64] reported that thickness of cookies developed from OFSP supplemented with wheat flour was reduced from 6.89 to 6.50 mm with the addition of more OFSP during the cookie development. They considered that the heat applied to cookies during baking decreased the thickness of cookies with more OFSP than wheat.

The spread ratio obtained in this study is in contrast with the report obtained by [34] who opined that the average spread ratio of wheat-OFSP-cashew nut cookies showed a significant decrease as the proportion of OFSP and cashew nuts flour was increased in the formulation. In their discovery, they suggested that the spread ratio of cookies is strongly correlated to the water absorption capacities of flour. Further research by [60] revealed that the "spread ratio of cookies has long been used as an important characteristic for determining the quality of flour for cookie production. Cookies with higher values of spread ratio are considered to be more desirable than those with lower values. Results obtained were similar to values (4.67 – 6.38) reported by [64] for wheat-bambara protein isolate-ripe banana mash cookies". However, [61] reported a significant (P = .05) increase in the spread ratio of the cookies with increasing level of malted barley bran (MBB) substitution from 0 to 50%, an observation [20] agreed with. According to [60] discovery, "doughs with lower viscosity cause cookies to spread at faster rate and vice versa". "They documented that the spread ratio of cookies increased with an increase in the content of non-wheat protein. Increase in spread ratio could also be attributed to an increase in the hydrophilic sites in the dough mixture leading to an increase in water absorption and swelling index" [65,66]. "The control of cookies spread ratio is a serious problem encountered during production; cookies that spread so much cannot be filled into the package and those that spread slightly causes slack fill or excess height for package, thus creating havoc on the packaging line" [61].

4. CONCLUSION

Value added cookies were produced from a blend of wheat, soybean and OFSP flours. The functional properties such as bulk density and WAC increased upon incorporation of OFSP and soybean flours while a decrease was observed in the swelling index. The proximate composition of the flours showed a significant increase in protein, ash, fat and fibre contents with substitution of soybean and OFSP. This implies an improvement in the quality of cookies and can add to the nutritional status of its consumers, especially children. Although the antinutritional properties of the flour and cookies increased with substitution of soybean and OFSP, they were below the critical limits as shown in the molar ratio. The physical properties of the fortified cookies were affected by the increased amount of OFSP.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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