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Nutritional Quality of Cookies Developed From Defatted Almond Seeds, Orange-Fleshed Sweet

Yağı Alınmış Badem Tohumları, Turuncu Etli Tatlı Patates ve Buğday Unu Karışımlarından Geliştirilen Bisküvilerin Besinsel Kalitesi

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ABSTRACT

The study assessed the nutritional quality, safety, and acceptability of cookies produced from composite flours containing wheat flour, defatted almond seed, and orange-fleshed sweet potato (OFSP). Cookies were formulated using three blends: MPQ (90% wheat flour, 5% OFSP, 5% defatted almond), KYB (85% wheat flour, 10% OFSP, 5% defatted almond), and DHL (80% wheat flour, 10% OFSP, 10% defatted almond). A commercially produced 100% wheat flour cookie served as the control. Standard cookie production procedures were applied, and analyses were conducted for proximate composition, selected vitamins (A, C, and E), minerals (potassium, phosphorus, sodium, iron, calcium, and magnesium), anti-nutrients (phytate, tannins, and saponin), sensory attributes, and total bacterial count using AOAC (2005) methods. Results showed that cookies from composite flours had higher crude ash (3.98–4.50%), fat (17.94–19.31%), fiber (5.05–5.18%), and protein (7.73–8.26%) contents compared to the control (1.70%, 17.31%, 1.30%, and 7.58%, respectively). Vitamin A, C, and E contents of the experimental cookies ranged from 1.60–2.17 IU/100 g, 0.012–0.017 mg/100 g, and 1.72–2.29 mg/100 g, indicating improved micronutrient density. While the control sample contained higher phosphorus and magnesium levels, sodium, calcium, and potassium were significantly lower (p>.05) in the control than in the composite samples. Sensory evaluation by 50 panelists showed high acceptability with minimal differences among samples, and microbial counts remained low. Overall, the study demonstrates that incorporating defatted almond seed and OFSP into wheat-based cookies enhances nutritional quality and may reduce reliance on imported wheat flour supporting commercial viability.

Keywords: orange-fleshed sweet potato, composite flour, cookies

ÖZ

Çalışma, buğday unu, yağı alınmış badem tohumu ve turuncu etli tatlı patates (OFSP) içeren kompozit unlardan üretilen bisküvilerin besinsel kalitesini, güvenliğini ve kabul edilebilirliğini değerlendirmiştir. Bisküviler üç farklı formülasyon kullanılarak hazırlanmıştır: MPQ (%90 buğday unu, %5 OFSP, %5 yağı alınmış badem), KYB (%85 buğday unu, %10 OFSP, %5 yağı alınmış badem) ve DHL (%80 buğday unu, %10 OFSP, %10 yağı alınmış badem). Ticari olarak üretilmiş %100 buğday unundan yapılan bisküvi kontrol örneği olarak kullanılmıştır. Standart bisküvi üretim yöntemleri uygulanmış; AOAC (2005) yöntemleri kullanılarak proksimat bileşim, seçilmiş vitaminler (A, C ve E), mineraller (potasyum, fosfor, sodyum, demir, kalsiyum ve magnezyum), antinutrisyonel faktörler (fitat, tanenler ve saponin), duyusal özellikler ve toplam bakteri sayısı analiz edilmiştir. Sonuçlar, kompozit unlardan üretilen bisküvilerin kontrol örneğine kıyasla daha yüksek ham kül (%3,98–4,50), yağ (%17,94–19,31), lif (%5,05–5,18) ve protein (%7,73–8,26) içeriklerine sahip olduğunu göstermiştir (kontrol: sırasıyla %1,70, %17,31, %1,30 ve %7,58). Deneysel örneklerin A, C ve E vitamini içerikleri sırasıyla 1,60–2,17 IU/100 g, 0,012–0,017 mg/100 g ve 1,72–2,29 mg/100 g aralığında olup mikrobesin yoğunluğunda artışa işaret etmiştir. Kontrol örneğinde fosfor ve magnezyum daha yüksek bulunurken, sodyum, kalsiyum ve potasyum düzeyleri kompozit örneklere göre anlamlı derecede daha düşük bulunmuştur (p>,05). Elli panelist ile yapılan duyusal değerlendirme, örnekler arasında büyük farklılıklar olmaksızın yüksek kabul edilebilirlik göstermiştir ve mikrobiyal yük düşük düzeyde kalmıştır. Genel olarak çalışma, yağı alınmış badem tohumu ve OFSP'nin buğday bazlı bisküvilere eklenmesinin besinsel kaliteyi artırdığını ve ithal buğdaya bağımlılığı azaltarak ticari uygulanabilirliği destekleyebileceğini ortaya koymaktadır.

Anahtar Kelimeler: Turuncu etli tatlı patates, kompozit un, bisküvi

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Introduction

Cookies are confectionery products baked to a low moisture content and widely consumed as convenient, ready-to-eat snacks across all age groups (Chinma et al., 2012; Usman et al., 2015). They are among the most popular bakery products due to their affordability, shelf stability, palatability, and nutritive value (Akubor, 2003).

Cookies contribute significant amounts of energy, iron, calcium, fibre, and B vitamins to daily dietary intake. However, conventional cookies are predominantly made from wheat flour, which limits the diversification of raw materials and opportunities for nutritional enhancement.

Wheat remains one of the most important cereal grains globally, ranking second after rice in worldwide production and trade (Falola et al., 2017). Despite its industrial versatility and potential for product diversification, overreliance on wheat flour in developing countries has driven the search for alternative, complementary raw materials suitable for bakery applications.

Orange-fleshed sweet potato (Ipomoea batatas) represents a nutritionally valuable tuber crop with significant potential in composite flour development. It is widely consumed in sub-Saharan Africa and ranks third in consumption after rice and wheat (Chandrasekara & Kumar, 2016). Sweet potato is rich in dietary fibre, minerals, vitamins, and antioxidants, including anthocyanins, phenolic acids, tocopherols, and β-carotene (Tang et al., 2015; Wang et al., 2016).

Processing sweet potato into flour enhances its shelf life and reduces post-harvest losses associated with transportation and storage challenges (Ngoma et al., 2019). Orange-fleshed sweet potato (OFSP), in particular, is a naturally biofortified crop rich in provitamin A carotenoids and has been identified as a sustainable dietary strategy to combat vitamin A deficiency.

Vitamin A plays a critical role in immune function, vision, and overall health. OFSP contributes β-carotene, starch, minerals, dietary fibre, and vitamins while also imparting natural sweetness, attractive colour, and desirable flavour to bakery products (Edun et al., 2019). (Prunus amygdalus) It is a nutrient-dense seed widely recognised for its high protein and micronutrient composition.

Although commonly referred to as a nut, it is botanically a seed native to the Middle East, India, and North Africa, and it is available in parts of Southern Nigeria. Almonds are consumed directly and used in oil extraction and flour production. They are rich in protein, riboflavin, niacin, vitamin E, and essential minerals, including calcium, copper, iron, magnesium, manganese, phosphorus, and zinc (USDA, 2018).

Almond seeds contain approximately 21.2% protein, with a 30 g serving providing 6.3 g protein (Ahren et al., 2005; United States Department of Agriculture, USDA 2018), and are rich in phytosterols (Shakerardekani et al., 2013). Beyond their nutrient density, almonds have been associated with cardiometabolic benefits, improved glycemic modulation, reduced postprandial plasma lipids, and antioxidant activity (Esquius et al., 2020; Palacios et al., 2020; Tan & Mattes, 2013).

The development of composite flours from nutrient-dense crops is recognised as an effective way to improve the nutrition of bakery products (Inyang et al., 2018; Nwosu et al., 2013). Composite flours blend cereals with protein- and micronutrient-rich ingredients to boost protein quality and micronutrient levels.

This approach helps address deficiencies from low protein or micronutrient intake, including vitamin A, iron, and zinc. Vitamin A deficiency (VAD) is a major public health challenge, affecting about 190 million preschool children and 19 million pregnant women, especially in Africa and South-East Asia (WHO, 2019). They are usually cereal-based and may lack enough protein and micronutrients. OFSP flour adds provitamin A; almond flour adds quality protein and key micronutrients. Including these ingredients in cookies creates a more nutritious and health-promoting product.

The study of the history of the use of composite flours dates back to attempts to partly replace wheat flour with local crops (Eriksson et al., 2014). Empirical evidence from various studies shows that it is possible to incorporate the flours of cereals, tubers, oilseeds, and legumes into bakery products (Méité et al., 2008; Olaoye et al., 2006).

Based on these results, the current research aimed to develop and test cookies made with wheat, orange-fleshed sweet potato, and almond flours, and specifically investigated the nutritional composition, functional characteristics, and overall quality attributes of the developed composite cookies to determine their suitability as value-added bakery products with enhanced nutrient density.

The present study also aims to address problems associated with micronutrient deficiency by developing nutritious alternatives and enhancing palatability based on cereal-tuber composite cookies.

Methodology

Study area

The sample preparation and experimental analysis were conducted at the Department of Human Nutrition and Dietetics Kitchen and Biology laboratory, Afe Babalola University, Ado-Ekiti, respectively.

Study Design

The experiment was conducted using a completely randomized design (CRD) with control and treatment groups. Each cookie formulation, including the control (100% wheat flour), was prepared in three replicates to ensure reproducibility and allow for statistical comparison.

Source of raw materials and preparation

Packed almond seeds, five kilograms were brought from a supermarket in Port Harcourt city, Rivers State, Nigeria. It was washed with tap water, drained, sun-dried, milled, packed in a plastic bag, and stored in a dry and cool place until further use. The almond sample was milled at a market in Ado-Ekiti. The flour was packed in a polyethene bag and stored at room temperature until further formulation with wheat and Orange flashed sweet potato flour. Four kilograms of Orange fleshed sweet potato (UMUSP002 variety) were brought from The Dietetics Department, University of Port Harcourt Teaching Hospital, and Rivers State. Then it was sorted, weighed, washed with clean tap water, peeled and cut into thin slices using a stainless steel knife, spread in a tray and oven (TR-TC-YHG-300-BS-11), dried at 60°C for ten hours and milled into flour by a local grinding machine in a market in Ado-Ekiti. The flour was packed in a polyethene bag and stored at room temperature for further formulation, product development, and composite flour nutritional and anti-nutritional analysis. Wheat flour was sourced from a grocery store in Port Harcourt city, Rivers State, Nigeria. The flour was packed in a polyethene bag and stored at room temperature for the further formulation, product development, and composite flour nutritional and anti-nutritional analysis.

Orange Fleshed Sweet Potato flour was prepared based on Oloniyo et al., (2018) OFSP flour preparation procedure. The following unit operations were employed: sorting, weighing, washing, peeling and cutting into thin slices by stainless steel knife, spreading in a tray and oven drying at 60^{o}C for ten hours and milling into flour.

The almond seeds were defatted and processed into flour using the method previously described by Tan and Mattes (2013). The almond (nuts) were sorted and dried in a hot air oven at 60 °C until dried and then milled, using a Philips laboratory blender (Philips HR2811 model, Amsterdam, Netherland). The resulting meal was defatted using n-hexane in a Soxhlet extraction apparatus as described by AOAC (2005). The defatted sample was air-dried in a fume hood at room temperature to drive off the n-hexane completely, the flour was blended by using a blender and thereafter sieved and preserved in a tightly closed plastic container pending use for the preparation of cookie samples.

Preparation of cookies

The sugar and butter were creamed together by hand until light and fluffy. To the sieved flour blends, baking powder and salt were added. To the creamed butter and sugar, eggs were beaten in. The flour mixture and batter were thoroughly mixed into the consistent dough. The dough was rolled on a flat wooden surface, cut and shaped using a cookie cutter. The dough was placed in pre-oiled trays and baked in a preheated oven at 130^{o}c for 25 minutes. The cookies were allowed to cool down to room temperature, packaged in polythene bags and stored for evaluation. The recipe and percentage of wheat flour, OFSP and defatted almond are presented in Tables 1 and 2 respectively. The flow diagram for the process is presented in Figure 1.

Table 1

Recipe for cookies from different portions of almonds, OFSP and wheat flour blends

INGREDIENTS	MPQ	KYB	DHL
Flour	500g	500g	500g
Butter	250g	250g	250g
Confectioners' Sugar	100g	100g	100g
Egg	60g	55g	62g
Salt	2g	2g	2g
Baking Powder	5g	5g	5g
Blends of flours for cookies production			
Samples	**Wheat Flour (%)**	**OFSP Flour (%)**	**Almond Flour (%)**
MPQ	90	5	5
KYB	85	10	5
DHL	80	10	10

Modified recipe of Omerie (2006)

WOA1= 90% wheat, 5% OFSP, 5% almonds; WOA2= 85% wheat, 10% OFSP, 5% almonds; WOA3= 80% wheat, 10% OFSP, 10% almonds

Figure 1

Flowchart of cookies preparation credit (Bello et al., 2020)

Preparation of raw ingredients

↓

Mixing of flour and sieve together

↓

Mix butter and baking powder

↓

Dry ingredients added into the cream

↓

Kneaded to make dough

↓

Rolled the dough and cut cookies

↓

Pre-heat oven at 150^{0}C for 15-20minutes

↓

Bake for 15-30 minutes at 130^{0}C

↓

Cookies cooled for 5-10 minutes and packed

Proximate composition of cookies

The proximate composition of crude protein, crude ash, crude fibre, crude fat, moisture and carbohydrate for the different compositions of cookies were determined using the official methods of the Association of Analytical Chemists (AOAC, 2005)

Mineral composition of cookies

To measure the composition of Calcium, Potassium, and Sodium, the ash of each sample obtained was digested by adding 5ml of 2M HCl to the ash in the crucible and heated to dryness on a heating mantle. 5ml of 2M HCl was added again, heated to boil, and filtered through a Whatman No. 1 filter paper into a 100ml volumetric flask. The filtrate was made up to mark with distilled water stoppered and made ready for reading of the concentration of Calcium, Potassium and Sodium on the Jenway Digital Flame Photometer (PFP7 Model) using the filter corresponding to each mineral element.

The concentration of each element was calculated using the formula:

$$\%Ca \text{ or } \%K \text{ or } \%Na = \frac{\text{Meter reading (MR)} * \text{Slope} * \text{Dilution factor}}{1000}$$

N.B: MR x slope x dilution factor will give you the concentration in part per million (ppm or mg/kg). Concentration in % was derived by dividing by 10000.

Iron content was determined using the Buck 200 Atomic Absorption Spectrophotometer (AAS) of AOAC (975:23) To determine the phosphorus content, the ash of each sample obtained was treated with 2 MHCl solutions as described for calcium determination above. 10ml of the filtrate solution was pipetted into a 50ml standard flask and 10ml of vanadate yellow solution was added and the flask was made up to mark with distilled water, stoppered and left for 10 minutes for full yellow development. The concentration of phosphorus was obtained by taking the optical density (OD) or absorbance of the solution on a Spectronic 20 spectrophotometer or colourimeter at a wavelength of 470nm.

Cookies Vitamin A determination

2g of the sample was weighed into a 250ml volumetric flask, containing 50ml of petroleum ether: Acetone (2:1v/v) mixture was added to extract the ß-Carotene. The flask containing the mixture was placed on a shaker to shake at 200rpm for 20min to ensure uniform mixing at room temperature. The mixture was later centrifuged at 4000rpm for 10min and the supernatant was collected and made up to 50ml with the solvent mixture. The supernatant was transferred to a 250ml separately funnel to separate the organic layer (upper layer). The aqueous layer was discarded and the organic layer was transferred into the 50ml volumetric flask and made up with a solvent mixture for reading of ß-carotene. Working standard of ß-carotene of range 0-50ppm or /ml were prepared from stock Beta carotene solution of 100ppm concentration. The absorbances of samples as well as working standard solutions were read on a Cecil 2483 UV Spectrophotometer at a wavelength of 450nm against blank.

Cookies' Vitamin C determination

10g of the sample was blended and homogenized with 50ml of 50% metaphosphoric acid-acetic acid solution. The mixture was quickly transferred into a 100ml volumetric flask and shaken gentle until a homogenous dispersion was obtained then it was diluted up to mark with 5% metaphoric acid-acetic acid solution. The mixture was filtered and the clear filtrate was stored in another 100ml volumetric flask prior to the spectrophotometric assay.

A few drops of bromine water were added to the filtrate above until the solution became coloured so as to confirm the completion of the oxidation of the ascorbic acid dehydroascorbic acid. This was followed by the addition of a few drops of thiourea to remove excess bromine to give a clear colorless solution.

A working standard of ascorbic acid of range 10-15µg/ml ascorbic acid, standard solution 5ml of 2,4-dinitrophenyl hydrazine solutions was added thoroughly to the sample extracts and working standards to give red colour after standing for 5mins. The absorbance of working standards, as well as sample extract, were read on Cecil 2583 spectrophotometer at a wavelength of 512nm.

$$\textbf{Vit C}\left(\frac{\textbf{mg}}{\textbf{100g}}\right) = \textbf{Absorbance of sample} * \textbf{Gradient factor} * \textbf{Dilution factor}$$

Cookies' Vitamin E determination

The estimation of Alpha-Tocopherol was done by the colourimeter method of Baker and Frank. The Alpha-tocopherol is determined based on the reduction by tocopherol of ferric to ferrous ions which then form a red complex with α, α'dipyridyl. Tocopherols and carotene are first extracted into xylene and the extinction is read at 460 nm to measure carotenes. A correction is made for these after adding ferric chloride and reading at 520 nm.

Anti-nutrient analysis of cookies

Tannins were extracted into boiling distilled water for one hour. Colour development was done with Folin-Dennis reagent and sodium carbonate solution. Absorbance was measured at 750nm spectrophotometrically. The tannic acid concentrations were calculated from the tannic acid standard curve. 0.20g of sample was measured into a 50ml beaker 20ml of 50% methanol was added and covered with parafilm and placed in a water bath at 77-80°C for 1 hour. It was shaken thoroughly to ensure uniform mixing. The extract was quantitatively filtered using a double layered Whatman No 41-filter paper into a 100ml volumetric flask, 20ml water added, 2.5ml Folin-Denis reagent and 10ml of 17% Na2CO3 were added and mixed properly. The mixture was made up to mark with water mixed well and allow to stand for 20 minutes. The bluish-green colour will develop at the end of the range. 0-10ppm were treated similarly to the 1ml sample above. The absorbance of the tannin acid standard solutions as well as samples were read after colour development on a spintronic 21D spectrophotometer at a wavelength of 760nm. % tannin was calculated using the formula:

$$\%\ \textbf{tannin} = \frac{\boldsymbol{Absorbance\ of\ sample * Average\ gradient\ factor * Dilution\ factor}}{\boldsymbol{weight\ of\ sample * 1000}}$$

Saponin was extracted for 2 hours in a reflux condenser containing pure acetone. Exhaustive re-extraction over heating mantle with methanol in the Soxhlet apparatus was done for 2 hours. The extract was weighed after allowing the methanol to evaporate. The saponin content was calculated as a percentage of the sample. To measure the amount of phytic acid in the sample, sample 2g was weighed into a 250ml conical flask and 100ml of 2% concentrated hydrochloric acid was used to soak the sample for 3 hours, followed by filtration through a double layer of hardened filter paper. 50ml of the filtration was placed in a 250ml beaker and 107ml of distilled water was added to give proper acidity. 10ml of 0.3% ammonium thiocyanate solution was then added to the solution as an indicator and was titrated with standard Iron III chloride solution containing 0.00195g iron per ml. the percentage of phytic acid was calculated using the formula.

$$\%\ \boldsymbol{phytic\ acid} = \frac{\%\ \boldsymbol{titre\ value} * \mathbf{0.0195} * \mathbf{1.19} * \mathbf{100}}{\mathbf{2}}$$

Total Bacteria Count

Plate count agar was used to determine the total bacteria loads of the sample. The media was prepared according to the manufacturer’s specification and autoclaved for 15 minutes at 121°C.25g of samples were introduced into the nutrient broth and mixed well. 1ml of the mixed broth was diluted in nine (9ml) of sterile distilled water followed by serial dilution up to 10-6. Using the pipette, 1 ml of the serial diluents 10-3 and 10-5 of the samples were aseptically introduced into different sterile plates, direct plating out was also done for each sample. A sterile prepared medium was introduced using the pour plate technique. The medium was allowed to be set and incubated at 37°C for 24 hours and the bacteria colonies were counted using a colony counter (Tankeshwar, 2015).

Sensory Evaluation

The formulated cookies and the control sample were subjected to sensory evaluation as described by Olagunju and Ifesan (2013). The samples were coded and served at room temperature to 50 untrained panellists. Panellists were selected randomly from the students of Afe Babalola University Ado Ekiti. The samples were coded MPQ, KBY, and DHL while the control sample was labelled sample “control”. Panelists were asked to rate the cookies samples based on taste, color, aroma, texture, crispness and overall acceptability. Their comments were also welcomed. Water was provided for the panelists to rinse their mouths after tasting each sample. Scores were based on a 9-point Hedonic scale ranging from dislike extremely (1) to like extremely (9).

Statistical Analysis

The results of the proximate analysis, vitamins, minerals and anti-nutrients were analyzed for statistical significance by One-Way Analysis of Variance (ANOVA) and data were reported as mean were applicable values at (p<.05) were regarded as significant in comparison. Statistical analyses were carried out using SPSS for Windows, version 20.0 (IBM SPSS Corp., Armonk, NY, USA).

Results

The results obtained from the proximate analyses of the cookies made from the different flour blends are presented in Table 2. The sample produced from 100% wheat flour was significantly lower (p<.05) than those from the composite flour in crude ash, crude protein, crude fibre and crude fat contents, but significantly higher (p<.05) in carbohydrate and moisture contents.

The crude ash, crude fat, crude fibre and crude protein contents of the cookies from the composite flour were within the ranges of 3.98–4.50%, 17.94–19.31%, 5.05–6.14%, and 7.73–8.26%, respectively, compared to 1.70%, 17.31%, 1.30% and 7.58% obtained for cookies produced from 100% wheat flour. Furthermore, 16.50% moisture and 55.61% carbohydrate were obtained for the control sample, compared to significantly lower (p<.05) ranges of 10.51–11.08% and 52.28–53.18%, respectively, in the composite samples.

An increase in the proportion of OFSP led to a significant increase (p<.05) in carbohydrate content, while a simultaneous increase in defatted almond significantly reduced (p<.05) carbohydrate levels. Crude protein and crude ash contents decreased significantly (p<.05) with increasing addition of OFSP and defatted almond. Crude fibre content decreased significantly (p<.05) with increasing OFSP but increased with increasing defatted almond proportion.

Table 2

Proximate composition of cookie samples

Samples	Moisture (%)	Ash (%)	Fat (%)	Crude Fibre (%)	Protein (%)	Carbohydrate (%)
MPQ	10.84 ± 0.00^c	4.12 ± 0.01^b	19.31 ± 0.00^a	5.18 ± 0.01^b	8.26 ± 0.01^a	52.28 ± 0.02^d
KYB	10.51 ± 0.01^d	3.98 ± 0.00^c	19.16 ± 0.02^b	5.05 ± 0.01^c	8.12 ± 0.03^b	53.18 ± 0.03^c
DHL	11.08 ± 0.01^b	4.50 ± 0.01^a	17.94 ± 0.01^c	6.14 ± 0.02^a	7.73 ± 0.03^c	52.61 ± 0.04^b
Control	16.50 ± 0.03^a	1.70 ± 0.03^d	17.31 ± 0.03^d	1.30 ± 0.03^d	7.58 ± 0.00^d	55.61 ± 0.06^a

Values are reported as mean ± standard deviation. a-d: mean values bearing different superscript letters within the same column differ significantly ($p < .05$).

MPQ: 90% wheat + 5% OFSP + 5% defatted almond, KYB: 85% wheat + 10% OFSP + 5% defatted almond

DHL: 80% wheat + 10% OFSP + 10% defatted almond, Control: 100% wheat flour

Vitamin Composition of Samples

The composition of β-carotene (vitamin A), ascorbic acid (vitamin C) and α-tocopherol (vitamin E) for both the control sample and experimental samples are presented in Table 4. Vitamin E, followed by vitamin A levels were the highest measured compared to vitamin C which was observed to be very low. The values obtained for vitamins A, C and E for the experimental samples were within the range of 1.60-2.17IU/100g, 0.012-0.017mg/100g and 1.72-2.29mg/100g respectively. The highest values for all were recorded vitamins in the cookie made from the lowest substitution of wheat with OFSP and defatted almond (i.e. 90% wheat flour + 5% OSFP + 5% defatted almond).

Table 3

Content of Selected Vitamins in the cookie samples

Samples	Vitamin A (IU/100g)	Vitamin C (mg/100g)	Vitamin E (mg/100g)
MPQ	2.17 ± 0.00^{a}	0.017 ± 0.001^{a}	2.29 ± 0.013^{a}
KYB	2.09 ± 0.00^{b}	0.015 ± 0.001^{b}	1.96 ± 0.004^{b}
DHL	1.60 ± 0.00^{c}	0.012 ± 0.001^{c}	1.72 ± 0.006^{c}
Control	0.60 ± 0.00^{d}	BDL	0.76 ± 0.000^{d}

Values are reported as mean ± standard deviation, and mean values bearing different superscript letters within the same column differ significantly ($p < .05$). BDL = Below Detectable Level.

Anti-nutrients Composition of Sample

Table 5 shows the results obtained for the antinutrient components of the samples. The results show the percentage of phytate, saponin and tannins. Cookies sample made from 100% contains no phytates, and also a significantly lower (p>.05) saponin and tannin content compared to the samples containing defatted almond and OFSP. The highest values were obtained for phytate and saponin at the highest OFSP: Defatted almond ratio. For tannin, the highest value was obtained at the highest substitution with OFSP and defatted almond (i.e. in sample DHL).

Table 4

Content of Selected Anti Nutrients in the cookie samples

Samples	Phytate (mg/100g)	Saponin (mg/100g)	Tannin (mg/100g)
MPQ	3.82 ± 0.006^{b}	0.76 ± 0.002^{b}	7.51 ± 0.005^{b}
KYB	4.17 ± 0.003^{a}	0.81 ± 0.003^{a}	6.13 ± 0.003^{c}
DHL	3.56 ± 0.005^{c}	0.73 ± 0.005^{c}	8.09 ± 0.012^{a}
Control	0.00 ± 0.00^{d}	0.45 ± 0.001^{d}	0.31 ± 0.001^{d}

Values are reported as mean ± standard deviation, and mean values bearing different superscript letters within the same column differ significantly ($p < .05$).

Mineral Composition of Sample

Results obtained for the composition of phosphorus, sodium, calcium, potassium, magnesium and iron in mg/kg are presented in Table 6. The results show very high phosphorus and magnesium contents in the control sample, significantly higher (p>.05) than in the experimental samples, and these two minerals decreased with an increase in substitution of wheat with OFSP and defatted almond. While sodium, calcium and potassium contents were significantly lower ($p>.05$) in the control samples, the highest values were obtained in the sample with the least substitution of wheat flour with defatted almond and OFSP i.e sample with wheat flour:OFSP: defatted almond ratio of 90:5:5. At higher OFSP and defatted almond contents the least values were obtained for sodium, calcium and potassium. Iron contents in the samples followed a different trend such that the least value was obtained for the sample with the highest OFSP ratio. All results obtained for minerals were significantly different (p>.05) in all samples.

Table 5

Content of Selected Minerals in the cookie samples

Samples	Phosphorus (mg/kg)	Sodium (mg/kg)	Calcium (mg/kg)	Potassium (mg/kg)	Magnesium (mg/kg)	Iron (mg/kg)
MPQ	105.25 ± 0.01^b	125.17 ± 0.15^a	206.30 ± 0.00^a	378.03 ± 0.25^a	34.51 ± 0.00^b	0.37 ± 0.00^c
KYB	90.44 ± 0.01^c	118.53 ± 0.15^b	192.47 ± 0.15^b	374.87 ± 0.15^b	28.62 ± 0.01^c	0.27 ± 0.01^d
DHL	87.38 ± 0.01^d	113.83 ± 0.25^c	158.67 ± 0.25^c	355.40 ± 0.20^c	22.15 ± 0.01^d	0.57 ± 0.00^b
Control	116.91 ± 0.00^a	16.42 ± 0.00^d	13.12 ± 0.00^d	141.05 ± 0.00^d	54.71 ± 0.00^a	2.87 ± 0.00^a

Values are reported as mean ± standard deviation.a-d:mean values bearing different superscript letters within the same column differ significantly (*p<.05*).

Sensory Evaluation of cookie samples

Mean values and standard deviation of sensory scores from 50 panellists that evaluated the samples are shown in Table 6. The result shows the level of the likeness of the samples based on some sensory parameters i.e. colour, aroma, taste, texture, crispness and overall acceptability. The control cookie sample produced from wheat flour which is conventional scored high for all parameters tested (mean value of 8.20 – 8.48 on a scale of 9), except for flavour where the average score obtained from the panellist was 7.80 on a 9-point hedonic scale. There was no significant difference (*p*<.05) in the aroma of all the samples – both experimental and control, meanwhile significant difference (*p*>.05) was observed for every other sensory parameter measured between the experimental samples and the control sample. For the experimental samples, the samples with equal proportions of OFSP and defatted almonds (i.e., 90:5:5 and 80:10:10) were the most accepted based on colour and texture. There was no significant difference (*p*<.05) observed between the mean scores obtained for the taste of the different experimental samples, although the mean values increased with an increase in the proportion of OFSP and defatted almond (i.e., from 6.96 – 7.08). The least sensory values, 5.40 and 5.88, were obtained respectively for the crispness and texture of the sample with wheat: OFSP: defatted almond ratio of 85:10:5. Apart from the control sample which was the most acceptable sample based on overall acceptability, the sample with the highest OFSP and defatted almond content scored high for overall acceptability (7.72) and was significantly higher (*p*>.05) than samples with lower OFSP and defatted almond quantities.

Table 6

Sensory Evaluation of cookie samples

Sample	Colour	Aroma	Taste	Texture	Crispness	Overall Acceptability
MPQ	7.92 ± 0.94^b	7.36 ± 1.03^a	6.96 ± 1.55^b	7.12 ± 1.38^b	6.08 ± 1.48^c	7.28 ± 1.23^c
KYB	7.20 ± 1.28^c	7.60 ± 1.25^a	7.04 ± 1.50^b	5.88 ± 1.75^c	5.40 ± 1.81^d	7.04 ± 1.16^c
DHL	7.76 ± 0.96^b	7.44 ± 1.18^a	7.08 ± 1.21^b	7.32 ± 1.42^b	7.32 ± 1.36^b	7.72 ± 0.93^b
Control	8.44 ± 0.81^a	7.80 ± 1.37^a	8.20 ± 1.31^a	8.40 ± 0.86^a	8.48 ± 0.91^a	8.36 ± 0.90^a

Values are reported as mean ± standard deviation, a-d: mean values bearing different superscript letters within the same column differ significantly (*p*<.05). 9-point hedonic scale (1 = dislike extremely; 9 = like extremely)

Total bacterial count of cookie samples

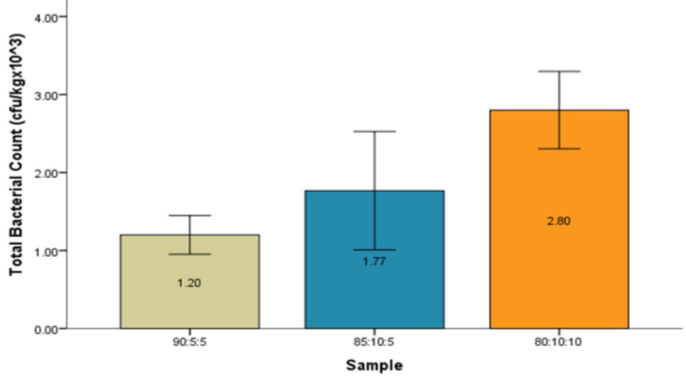
The total bacterial count (TBC) of the experimental cookies samples in colony forming unit per metric kilogram is presented in the graph in figure 2. Results show that the bacterial count of the cookies samples increased significantly (*p*>.05) with an increase in the amount of OFSP and defatted almond added. TBC of the samples ranged from 1.20-2.80cfu/kg*103.

Discussion

The proximate composition results provide insight into the quality and storage stability of the developed composite cookies. Moisture content is a critical quality parameter influencing shelf life and microbial stability. In this study, cookies produced from 100% wheat flour recorded a significantly higher (p>0.05) moisture content compared to composite cookies formulated with wheat, OFSP, and

Figure 2

Total Bacterial Count of Cookies Samples



Data are mean values of triplicate determinations ± standard deviation; Samples are bars are labelled as wheat flour: OFSP: Defatted almond ratio *all values are significantly different

defatted almond flours. This observation aligns with Kebero (2021), who reported moisture contents of 13.02% and 7.84% for wheat and OFSP, respectively. Similar findings were reported by Kolawole et al. (2020), who observed higher moisture content in wheat cookies (15.33%) compared to composite cookies (12.04–13.00%). The reduction in moisture content observed with OFSP substitution suggests improved keeping quality of the developed composite cookies, as low moisture content reduces susceptibility to spoilage (Ijarotimi et al., 2021). However, although substitution improved moisture reduction, the overall moisture levels of the samples remain above recommended limits for extended storage (Bello et al., 2020), indicating that further process optimization may enhance product stability.

Ash content, an index of total mineral composition, increased markedly with increasing inclusion of OFSP and defatted almond flour. A 10–20% substitution resulted in a 134–165% increase in ash content relative to the control. This confirms that the composite formulation enhanced the mineral density of the cookies. Similar increases in ash content following OFSP incorporation were reported by Edun et al. (2019) and Kebero (2021). The highest ash value recorded at maximum inclusion levels demonstrates the nutritional advantage of the developed composite cookies over conventional wheat cookies.

Fat content significantly increased in the composite samples, contributing to enhanced energy density. Although both OFSP and defatted almond were included, results suggest that the fat increase was influenced by the OFSP proportion, as higher OFSP ratios corresponded with higher fat values. This trend agrees with Kolawole et al. (2020), who reported similar observations in OFSP-based cookies. The elevated fat content enhances caloric contribution and may positively influence mouthfeel and sensory perception of the developed product.

Crude fibre content increased 3.8–4.7 times following 10–20% substitution with OFSP and defatted almond. Dietary fibre plays essential physiological roles including improved bowel movement, modulation of gut microbiota, and cholesterol reduction (Slavin, 2013). Similar increases in fibre content with OFSP incorporation were documented by Edun et al. (2019) and Kebero (2021). The substantial fibre improvement in the composite cookies represents a significant functional enhancement compared to conventional wheat cookies.

Protein content showed a slight increase at lower substitution levels but declined as OFSP proportion increased. This trend agrees with Xu et al. (2020) and Kebero (2021). The results suggest that while defatted almond contributed positively to protein enrichment, higher OFSP inclusion diluted overall protein concentration due to its lower protein content relative to wheat. Therefore, optimal formulation balance is required to maximize protein enrichment without excessive dilution effects. These findings confirm that wheat flour possesses higher protein content than OFSP but lower than defatted almond (Kebero, 2021), supporting the rationale for strategic composite blending.

Vitamin composition was influenced by both ingredient inclusion and thermal processing. Although vitamin levels decreased with increasing OFSP and almond proportions in some instances, composite samples generally recorded higher vitamin contents than the control, likely due to OFSP inclusion. OFSP is recognized for its provitamin A content (Edun et al., 2019). However, heat-sensitive vitamins may have been partially degraded during baking (Nzamwita et al., 2017). The low vitamin levels in the control sample may be attributed to wheat flour refinement and the relative instability of certain vitamins during processing.

Antinutritional factors were within safe limits. Phytate levels were lower than those reported for pumpkin seed (35.06 mg/100g) (Elinge et al., 2012) and lower than values reported for sprouted sorghum, pigeon pea, and OFSP flour blends. Tannin values were below the permissible level of 90 mg/100 g (Ifie and Emeruwa, 2011). Thermal processing during baking likely contributed to reduced antinutritional factors through denaturation and complex formation (Kataria et al., 1998). These complexes are typically associated with outer grain layers such as the aleurone and pericarp (Cheryan, 1980). Additionally, phytate levels in wheat flour are influenced by milling processes, with refined white flour containing minimal phytate (Kebero, 2021). The low antinutrient levels observed indicate good mineral bioavailability potential of the developed composite cookies.

Mineral analysis revealed higher sodium, calcium, potassium, and magnesium contents in composite samples, largely attributable to defatted almond inclusion. Slight reductions were observed with increased OFSP proportions, suggesting that almond contributed more substantially to mineral enrichment. Calcium and phosphorus play essential roles in bone formation, metabolic regulation, and cellular function (Wardlaw, 2004). Iron retention is expected during baking since it is heat stable (Miller, 2008). Overall, the mineral composition indicates that the developed composite cookies can contribute meaningfully to recommended dietary allowances (Potter and Hotchkiss, 2006), reinforcing their nutritional value.

Sensory evaluation remains critical in determining consumer acceptance of novel products. As expected, the 100% wheat control scored highest across most sensory parameters due to consumer familiarity. However, composite cookies demonstrated good acceptability, particularly at the 80:10:10 wheat:OFSP:defatted almond ratio, which emerged as the most preferred experimental formulation. OFSP inclusion enhanced colour and taste, likely due to its natural sweetness and β-carotene pigment (Edun et al., 2019; Kebero, 2021). Similar improvements in colour and acceptance with OFSP incorporation were reported by Owade et al. (2018) and Kindeya et al. (2021). Appearance and colour significantly influence consumer perception (Surkan et al., 2009), and the attractive hue imparted by OFSP likely enhanced visual appeal.

Crispness, an important quality attribute of cookies, was highest in the 85:10:5 formulation. Reduced crispness in some samples may be associated with moisture levels above 10%, which can affect textural integrity. Nonetheless, all composite formulations were generally acceptable, demonstrating that incorporation of OFSP and defatted almond can produce nutritionally enhanced cookies without compromising overall sensory quality.

Conclusion and Recommendation

The accumulative results from this study show that substitution of a portion of wheat flour for cookies with a proportion of defatted almond and OFSP increases the nutritive value of the cookies, for instance, it increases the proximate values of the samples (i.e. crude ash, crude from protein, crude fat and crude fibre), except moisture and carbohydrate which is slightly reduced. Cookies from OFSP and defatted almonds also have a higher vitamin A, C and E constant compared to traditional cookies. It is also richer in minerals including sodium, calcium and potassium compared to traditional cookies. The experimental cookie blends also show high acceptability for various sensory qualities including colour, aroma, taste, texture, crispness and overall acceptability. The experimental samples have a very low anti-nutrient factor which is desired in food materials.

The use of composite flour from wheat, defatted almond and OFSP, from this research, will be an avenue for high-quality nutritious cookies product and a means of reducing the huge amount spent on the importation of wheat flour (Nwosu et al., 2013; Inyang et al., 2018). The products can be produced commercially as it has very high acceptability.

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