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Proximate, mineral and vitamin analysis of formulated nutrients enriched gluten-free scones developed from orange-fleshed sweet potato, lima beans and sorghum blends

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ABSTRACT: Gluten-free bakery products often lack protein, fibre, and micronutrients because they do not contain wheat or other gluten-rich cereals. These deficiencies can be addressed through targeted fortification during formulation. This study aimed to develop nutrient-enriched gluten-free scones using blends of orange-fleshed sweet potato (OFSP), lima bean, and sorghum flours and evaluate their nutritional quality for Coeliac consumers. Using a completely randomised design implemented via Design-Expert, five flour blends were formulated in the following ratios of OFSP: lima bean: sorghum (%): A (0:0:100), B (5:5:90), C (5:15:80), D (10:5:85), and E (5:25:70). Proximate composition (moisture, protein, fat, ash, fibre, carbohydrate), minerals (Na, Mg, Ca, Fe, P), and vitamins (A and C) were determined. Significant differences ($p \leq 0.05$) were observed among blends for all nutritional parameters. Sample E (5% OFSP, 25% lima bean, 70% sorghum) had the highest protein (26.85%), fat (13.87%), fibre (4.83%), and ash (10.63%) contents, while moisture and carbohydrate were lowest. Mineral (Na, Mg, Ca, Fe, P) and vitamin (A and C) contents had significant differences, with sample D showing the highest vitamin A (8.96 µg/100g) and vitamin C (6.55 mg/100g). The results suggest that gluten-free scones enriched with OFSP and lima bean can have nutritional profiles comparable to those of conventional wheat-based scones. Samples D and E demonstrated superior protein and provitamin A levels, making them promising formulations for gluten-intolerant consumers.

Keywords: Coeliac disease, gluten-free scones, lima bean flour, orange-fleshed sweet potato, nutritional assessment, sorghum.

INTRODUCTION

Coeliac disease is an autoimmune disorder in which ingestion of gluten triggers an immune response that damages the small intestine, leading to malabsorption of nutrients. Hence, existing research has shown that gluten-free diets are essential for individuals with coeliac disease and have gained popularity among the general population due to perceived health benefits (Adebayo-Oyetoro *et al*., 2017; Omobuwajo, 2003). However, developing gluten-free baked products remains challenging because the absence of wheat gluten compromises both structural and nutritional quality. Consequently, many gluten-free products have lower protein, fibre, and vitamin contents and often exhibit reduced shelf life (Ardoin *et al.,* 2023). Alternative flours such as rice, maize, sorghum, millet, or cassava provide starch but lack the viscoelastic proteins that trap gas and retain moisture. As a result, gluten-free doughs tend to lose structure during baking, producing dense or crumbly textures unless supplemented with hydrocolloids or gums (Painter and McGinnis, 2024).

Efforts to address these limitations focus on composite flours and fortification strategies. Key challenges include increasing protein and fibre levels, supplying essential micronutrients such as vitamin A, and enhancing water-binding capacity to prolong freshness (Gallagher *et al.,* 2004; Phimolsiripol *et al*., 2012). Legume flours and pulses are promising, as they provide lysine-rich protein (an essential amino acid often limited in cereals), increase fibre content, and enhance dough viscosity and water retention (Imam *et al*., 2024; Mouminah and Althaiban, 2025). These properties enhance the crumb structure and loaf volume. In addition to legumes, incorporating provitamin A-rich ingredients, such as orange-fleshed sweet potato (OFSP), can provide β-carotene, which may help address vitamin A deficiency in gluten-free diets.

Against this background, the present study aimed to formulate nutrient-enriched, gluten-free scones using OFSP, lima bean and sorghum flours and to evaluate their nutritional properties as potential alternatives for gluten-intolerant consumers.

Orange sweet potato flour is a nutrient-rich flour made from the orange sweet potato tuber. It is known to be rich in beta-carotene, a precursor of vitamin A, which helps prevent vitamin A deficiency in developing countries (Aidoo *et al.,* 2022). Orange-fleshed sweet potato is a biofortified variety that contains higher levels of β-carotene than conventional tubers (Rodrigues *et al*., 2016). Orange sweet potato has great potential for use in food production.

Lima bean, known as butter bean, is a type of legume that belongs to the *Phaselus lanatus* species. It is high in protein, fibre and various essential vitamins and minerals (Adebo, 2023). Lima bean flour is a nutritious and healthy option for celiac patients due to its natural gluten-free properties, fibre, protein, vitamins, minerals, and its role in regulating blood sugar. Lima beans are widely cultivated and consumed globally, particularly in tropical and subtropical regions. Lima beans are an excellent source of plant-based protein, fibre and various essential nutrients. Lima beans are high in protein, making them an excellent option for vegetarians and vegans (Adebo, 2023).

Sorghum (*Sorghum bicolor*) is a sprouted or germinated cereal with activated nutrients that are bioactive. Sorghum is a cereal belonging to the gluten-free family and ranks sixth in the world in harvested area, covering 4.8 million hectares in 2022 (Adem and Abera, 2024). However, cereals are generally low in protein and are deficient in the essential *amino acid***s** lysine and tryptophan (Peter, 2025). Sorghum is gluten-free, so that celiac sufferers can go for sorghum as their source of grains instead of wheat. Sorghum is grown worldwide to provide basic nutrition for many developing nations.

Specifically, the study determined the proximate composition (moisture, protein, fat, fibre, ash and carbohydrate) of scones made from 100% sorghum flour and from blends of OFSP, lima beans and sorghum; it further assessed the mineral composition (for example Ca, Fe, Mg, Na and P) of the control and blended scones; and it measured the vitamin profile, with particular attention to provitamin A and vitamin C, in order to establish the micronutrient advantages of incorporating OFSP and legume flour into a sorghum-based, gluten-free matrix. By doing so, the research explored the potential of OFSP–lima bean–sorghum blends to produce nutrient-dense, accessible gluten-free scones suitable for coeliac patients, while also contributing to broader nutrition and health priorities reflected in the United Nations Sustainable Development Goals 2 (Zero Hunger) and 3 (Good Health and Well-being).

MATERIALS AND METHODS

Product selection and justification

In this study, the scone was selected as the product vehicle. Scones were chosen because their simple recipe and flexibility allow easy substitution of flours and nutrient fortification without specialised equipment.

Ingredients and flour preparation

For the formulation experiments, orange-fleshed sweet potatoes (OFSP) (*Ipomoea batatas* L.), lima beans (*Phaseolus lunatus*), and sorghum grain (*Sorghum bicolor*) were used. Essentially, these three crops were selected for their complementary nutritional profiles and their widespread availability as inexpensive, gluten-free staples in many regions. Each raw material was procured in equal quantities (2 kg) from a local market in Owerri, Imo State, Nigeria and processed under identical conditions on the same day to ensure comparability. After cleaning and sorting to remove debris, each raw material was processed into flour as detailed below:

Orange-fleshed sweet potato (OFSP)

The tubers were washed, manually peeled, and sliced into thin pieces (2mm thick). As done in previous studies (Nwakanma *et al*., 2022; Nwakanma *et al*., 2024), to prevent enzymatic browning and colour loss, the slices were soaked in a 1% potassium metabisulphite solution for 30 minutes before drying. Drying was done in a hot-air oven at 65°C until the slices were brittle. The dried sweet potato chips were then milled using an attrition mill and sieved through a 250 μm mesh to obtain a fine orange-fleshed sweet potato flour. The flour was stored in an air-tight container until use. OFSP flour has a bright orange colour due to its high *β*-carotene content and contributes sweetness, viscosity, and dietary fibre to the dough.

Lima bean

The lima beans (Phaseolus lunatus) were rinsed, manually dehulled to remove the bitter, fibre-rich testa, and the cotyledons were then oven-dried at 50°C for about 4 hours to reach low moisture, following the low-temperature hot-air protocols commonly used for lima bean flour (Pham *et al.,* 2022; Segura-Campos *et al*., 2010). The dried beans were milled and sieved to obtain a fine (250 μm) off-white flour, which typically contains 18–24 % protein together with complex carbohydrates and dietary fibre (Ogechukwu and Ikechukwu, 2021). Amino-acid profiling shows that lima bean is particularly rich in lysine, about 1.0 g lysine per 100 g dry seed (1,014 mg/100 g), equivalent to 6–7 g lysine per 100 g protein, making it an excellent complement for lysine-deficient cereals (Meredith and Thomas, 1982; Palupi *et al*., 2022). Because lysine is the first limiting essential amino acid in sorghum- and rice-based gluten-free systems, incorporating lima bean flour improves overall protein quality and water absorption. Consistent with this, prior research on gluten-free bakery products shows that partial replacement of cereal flours with legume flours (beans, chickpeas, peas, lentils, Phaseolus spp.) significantly increases total protein and raises the lysine content of the final product (Foschia *et al.,* 2017; Gularte *et al.,* 2011).

Sorghum

The sorghum grains were first cleaned to remove visible impurities, lightly rinsed, and air-dried before milling. Because sorghum is a naked caryopsis, no dehulling step was required; only extraneous matter (dust, stones, broken seeds) was removed before milling, consistent with sorghum handling in cereal–legume composite studies (Nwakanma *et al.,* 2024; Painter and McGinnis, 2024). Using the same laboratory mill, the dried grains were milled and sieved to obtain a fine sorghum flour (250 μm), which typically presents a pale-cream colour, mild flavour, and a naturally gluten-free starch base with modest protein and proper levels of minerals such as magnesium and iron (Painter and McGinnis, 2024; Ardoin *et al*., 2023). Although sorghum storage proteins (kafirins) do not form gluten-like networks, sorghum flour has been applied at high inclusion levels in gluten-free breads, giving acceptable loaf quality when formulated with gums, hydrocolloids or complementary flours (Ardoin *et al.,* 2023; Painter and McGinnis, 2024). This aligns with current evaluations of sorghum as a climate-resilient, drought-tolerant cereal suitable for nutrition-improvement interventions in dry and marginal environments, making its use in gluten-free products a socially responsible option (Painter and McGinnis, 2024).

All flours produced in this study were packed in clean, airtight containers, stored at ambient (room) temperature, and used within 1 month to limit moisture uptake and rancidity, following good storage practices reported for cereal–legume flours (Adegoke and Adebayo, 1994; Arogba *et al.,* 1998). The other scone ingredients were kept constant across formulations: granulated sugar, powdered milk (to enhance protein content and flavour), baking powder as the leavening agent, a small amount of salt, vanilla flavour, and fat and aqueous phases. Margarine and water (or milk) were used to develop the scone dough structure, consistent with composite-flour baked products formulated in related Nigerian and West African studies (Adebayo-Oyetoro *et al*., 2017; Nwakanma *et al*., 2022; Omobuwajo, 2003).

Experimental flour blend formulations

A completely randomised design (CRD) was used to assign different flour blend ratios to scone samples. Five formulations (labelled A through E) were initially developed (Table 1). These included a control (Sample A) made from 100% sorghum flour and four composite blends incorporating varying proportions of OFSP and lima bean flours in place of some sorghum flour. The total flour content was fixed, so each blend's components sum to 100%.

In Formulations B–E, sorghum flour is partially replaced by OFSP and lima bean flour to achieve dual fortification. The design was chosen to explore a range of lima bean substitution levels (5% to 25%) and a modest addition of OFSP (5% or 10%) without overwhelming the flour matrix. Based on preliminary trials and literature on similar products (Adebayo-Oyetoro *et al*., 2017; Nwakanma *et al.,* 2022; Omobuwajo, 2003), these ranges were expected to produce scones with noticeable nutritional enhancement while maintaining workable dough consistency.

Along with the flour blends, a consistent base recipe was used for all scone samples. Each batch consisted of 800g of total flour, to which other ingredients were added in fixed amounts (Table 2). This standardisation ensured that differences in outcomes could be attributed to the flour composition rather than variations in the recipe.

Scone preparation procedure

The oven was preheated, and a baking sheet was lined with parchment paper. Orange-fleshed sweet potato, lima beans, sorghum flour, sugar, baking powder, and salt were combined in a food mixer and stirred to form dough. The detailed recipe used is presented in Table 2. Margarine was cut into pieces and added to the mixture. With the mixer on low speed, the ingredients were blended until a cream-like texture formed. Enough milk was added to achieve a thick cream consistency. Once a homogeneous dough was obtained, it was divided into two equal portions, flattened into disc-shaped forms about 1.5 inches thick, and baked in a preheated oven at 180°C for 20 minutes. All scones were made on the same day to minimise variability in ambient conditions. The baked scones were allowed to

Table 1. Gluten-free scone flour blend formulations (percentage of each flour by weight).

Samples	OFSP flour (%)	Lima bean flour (%)	Sorghum (%)
A	0	0	100 (Control)
B	5	5	90
C	5	15	80
D	10	5	85
E	5	25	70

Key: Sample A = 100% Sorghum flour (Control), Sample B = 5:5:90 (OFSP: Lima bean: Sorghum flour), Sample C = 5:15:80 (OFSP: Lima bean: Sorghum flour), Sample D = 10:5:85 (OFSP: Lima bean: Sorghum flour), Sample E = 5:25:70 (OFSP: Lima bean: Sorghum flour).

Table 2. Base recipe for gluten-free scones (quantities for a batch with 800g total flour).

Recipe	Quantity (g)
Composite flour blend (A–E)	800
Margarine (shortening)	100
Granulated sugar	100
Powdered milk	50
Baking powder	10
Vanilla flavour	2
Salt	2
Water or milk (to mix)	200–250 ml approximately

Note: The powdered milk and sugar were kept constant for all samples, providing additional nutrients and sweetness, respectively. No eggs were used to ensure the protein differences come primarily from the flours. Margarine contributes fat for texture but no gluten.

equilibrate (24 hours) and then finely ground for compositional analyses.

Proximate and nutrient analysis

Each scone sample (A–E) was analysed for proximate composition (moisture, crude protein, fat, crude fibre, ash, carbohydrate by difference) and selected minerals and vitamins. Analyses were conducted following AOAC (2020) standard procedures, including the Micro-Kjeldahl method for protein determination (Bradstreet, 1954). All measurements were done in triplicate, and results are reported as mean ± standard deviation on a dry-weight basis (except moisture). The methods have been implemented in our previously published work (Nwakanma *et al.,* 2022; Nwakanma *et al*., 2024). Please refer to these papers for more details. Find below a summary of the process implemented.

Moisture content

Approximately 2g of the ground sample was weighed in a pre-dried crucible and then oven-dried at 105°C for 3 hours. The crucible was cooled in a desiccator and reweighed. Drying was repeated until a constant weight was reached. Moisture content (%) was calculated as:

% Moisture = (Weight loss / Weight of sample) × 100

Ash content

About 2g of sample was placed in a clean crucible and incinerated in a muffle furnace at 550°C for several hours until a light grey ash was obtained (complete combustion of organic matter). The residue was cooled and weighed. Ash content was calculated as:

% Ash = (Weight of ash / Weight of original sample) × 100

Crude protein

Crude protein was determined using the Micro-Kjeldahl method (Bradstreet, 1954). One gram (1g) of each sample was digested with 0.12g $CuSO_4$, 2.50mL concentrated H2SO4, 3g selenium catalyst, and anti-bumping chips, heated until transparent. The solution was then cooled and diluted with 80ml distilled water, and distilled to 50 ml of 2% boric acid containing methyl red indicator. Distillation continued until 100 mL of distillate was collected; 10ml of the distillate was titrated with 0.649 mol/L H_2SO_4 to a pink endpoint. Nitrogen percentage was calculated as:

%N = (Titre - Blank) × Normality of acid × N factor) / Weight of sample

Crude Protein (%) = %N × 6.25

Crude fat

Two grams (2 g) of the sample were placed in a dried thimble and weighed (W_2). A round-bottom flask charged to three-quarters with *n*-hexane (ca. 60 °C) was attached to a reflux condenser; samples were extracted under reflux for 4 hours. Solvent was recovered; the flask containing the extracted oil was dried and weighed. Fat content was calculated as:

% Fat = (Weight of fat extract / Weight of sample) × 100

Crude fibre

Two grams (2 g) of defatted sample were boiled under reflux for 30 min in 200 ml of 1.25% H_2SO_4, filtered and washed with hot water, then returned to the flask with 200 ml of 1.25% NaOH and boiled under reflux for another 30 min. The residue was filtered, transferred to a pre-weighed crucible, dried at 105 °C to constant weight (W_2), incinerated at 550 °C, cooled in a desiccator, and reweighed (W_3). Crude fibre was calculated as:

% Crude fibre = (Weight loss / Weight of sample) × 100

Carbohydrate content

The carbohydrate content of the samples was determined by difference. Thus, carbohydrate content was calculated as:

% Carbohydrate = 100 − ($M + A + P + CF + F$)

Where: M = Moisture content (%), A = Ash content (%), P = Protein content (%), CF = Crude fibre content (%), F = Fat content (%)

The mineral analysis of the gluten-free scone samples was analysed to determine potassium, magnesium, calcium and iron, *β*-carotene and vitamin C contents using standard laboratory procedures. Each parameter was assessed individually as described below.

Potassium content

A potassium chloride solution (0.254 g KCl in 1 L distilled water) was prepared to yield 100ppm potassium. This working standard was diluted to prepare a range down to 0.10ppm. A 2 mL sample aliquot was diluted to 100 mL. Both standards and samples were read in a flame photometer using a potassium filter, and the photometer readings were noted. The potassium concentration in the sample was determined from the standard calibration curve using the formula:

K = (Graph reading × V × DF) / (104 × W × a)

Where: *K* = potassium concentration, *V* = solution volume, *DF* = dilution factor, *W* = sample weight, and *a* = aliquot volume.

Magnesium content

To prepare standards, 0.10 ml of the working solution was diluted to 100 ml, giving 0.10 ppm magnesium. A 2 ml aliquot of the sample was mixed with 3ml NaOH (added incrementally with mixing). Absorbance was measured at 530 nm. The concentration of magnesium in the sample was determined from the standard calibration curve using:

Mg = (Graph reading × V × DF) / (140 × W × a)

Where: Mg = magnesium concentration, V = solution volume, DF = dilution factor, W = sample weight, a = aliquot volume.

Calcium and iron

Calcium and iron were determined by titration. A clean delivery tube was attached to a 0.08M EDTA titration cartridge, flushed, and calibrated. A 25 ml aliquot of the sample digest was transferred to a titration flask, followed by the addition of 2 ml of potassium hydroxide. The solution was titrated with 0.08M EDTA until the colour changed from pink to blue. Concentrations were determined using calibration standards.

Vitamin analysis

β-carotene Content (Precursor of Vitamin A)

Five grams (5 g) of the sample were weighed into a 250 ml separating funnel. 2 ml NaCl solution was added, then shaken vigorously, followed by 10 ml ethanol and 20 ml methanol. The mixture was shaken for 5 minutes, allowed to stand for 30 minutes, and the lower layer was discarded. Absorbance was measured at 460 nm using a UV-Visible spectrophotometer (Model UV-1800, Shimadzu Corporation, Japan). *β*-carotene concentration was calculated as:

β-carotene = Absorbance / (ε × l)

Where: ε = specific extinction coefficient, l = path length of the cuvette (1 cm).

Additional constants: Molar extinction coefficient, Σ = 15 × 10^{-4}, and Molar mass of β-carotene = 536.88 g/mol

Specific extinction coefficient = Σ× molar mass of β-carotene

Vitamin C

Vitamin C was determined using the Barakat titrimetric method as described by Changes in AOAC Official Methods of Analysis (1998). Five grams (5 g) of the sample were homogenised in 100 ml of EDTA extract solution for 5 minutes, then filtered. The filtrate volume was adjusted to 100 ml with additional extraction solution. A 20 ml aliquot was pipetted into a conical flask, to which 10 ml of 20% potassium iodide and 5 ml starch indicator were added. The mixture was titrated against 0.01 mL of $CuSO_4$ solution to an endpoint indicated by black specks. Vitamin C content was calculated as:

$$\text{Vitamin C (mg/100 g)} = (100 \times V_F \times 0.88) / (W \times V_A)$$

Where: W = weight of analysed sample (g), V_F = total volume of extract (ml), V_A = volume of aliquot used for titration (ml).

Statistical analysis

For each response variable, descriptive statistics (mean and standard deviation) were computed to characterise central tendency and within-treatment variability. Because the experimental factor (flour blend) had a single fixed effect with five levels, a one-way analysis of variance (ANOVA) was used for each response variable. When the ANOVA F-test was significant at $p \leq 0.05$, multiple-comparison procedures were applied to identify which formulations differed. All analyses were performed using IBM SPSS Statistics version 20 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at $\alpha = 0.05$ for all tests. Results are reported as mean ± standard deviation (n = 3).

RESULTS AND DISCUSSIONS

Proximate composition of scones using orange-fleshed sweet potato, lima beans and sorghum flour

The proximate composition of the samples evaluated included moisture, protein, fat, ash, crude fibre, and carbohydrate. The results are detailed in Table 3. Moisture, crude protein, fat, crude fibre, ash, and carbohydrate contents varied significantly ($p \leq 0.05$) among samples.

The moisture content of the samples ranged from 5.57% for sample E to 8.60% for sample A. The values obtained from this study were within the acceptable limit of scones (Okoye and Okaka, 2009). The relatively low moisture content of sample E showed that sample E will have a longer shelf life due to low moisture content as a result of the dehydration mechanism used during the production of sample E. Also, the relatively low moisture content of sample E will inhibit the growth and activity of contaminating micro-organisms, whose growth and activities are favoured by moisture (Okezie and Bello, 1988). Crude protein content of the samples ranged from 19.52% for sample A to 26.85% for sample E. The high crude protein content of sample E could be attributed to the ingredients used during production, which showed increased protein and ash contents with higher lima bean substitution, reflecting the protein density of legumes, consistent with findings by Okoye and Okaka (2009), who observed similar protein enhancement in legume-enriched baked goods.

Fat content of the scone samples ranged from 9.17% for sample A to 13.87% for sample E. The fat content of the samples was significantly different ($p \leq 0.05$). Sample A had the least fat content, which could be attributed to the absence of lima flour. The fat content of any food sample contributes to improved mouthfeel and flavour. It will also help improve the texture of scone food samples, thereby increasing consumers' demand (Ibe *et al*., 2024).

Crude fibre content of the scone samples ranged from 0.87% in the sorghum-only control (sample A) to 4.83% in the most extensively fortified blend (sample E), showing that inclusion of OFSP and lima bean substantially increased dietary fibre relative to the base cereal formulation, in line with reports that legume–tuber fortification improves fibre in gluten-free products (Imam *et al.,* 2024; Foschia *et al.,* 2017). This level of fibre is nutritionally desirable because dietary fibre enhances laxation and helps prevent constipation, supporting overall gastrointestinal health (Painter and McGinnis, 2024). Moreover, fibre and resistant-starch fractions from cereal–legume systems have been associated with reduced risk of diet-related noncommunicable diseases, particularly type 2 diabetes, cardiovascular disease, obesity and colorectal disorders through improved glycaemic response, lipid modulation, and colonic fermentation to butyrate (Alsaffar, 2011; Painter and McGinnis, 2024). These findings therefore corroborate the present study's observation that legume- and OFSP-enriched gluten-free scones can deliver not only higher fibre but also potential long-term health benefits.

Ash content of the scone ranged from 6.48% for sample A to 10.63% for sample E. This significant increase indicates that substituting OFSP and lima beans enhanced the mineral content of the scones. The control (100% sorghum) had the lowest ash content, while sample E had the highest, aligning with the mineral analysis results. Also, the ash content values obtained in this study are higher when compared to the range 0.64% to 0.92% reported by Adegoke and Adebayo (1994).

Carbohydrate content decreased from 54.75% (A) to 38.25% (E), showing an inverse relationship with the protein, fat, and ash contents. This trend occurs because nutrient-dense flours replaced part of the sorghum starch fraction, leading to a more balanced macronutrient profile. These findings confirm earlier reports by Phimolsiripol *et al.* (2012) that substitution with protein- and fibre-rich flours lowers carbohydrate concentration in gluten-free formulations.

Table 3. Proximate composition of gluten-free scones (%, on dry weight basis). Values are mean ± SD (n = 3). Different superscript letters within a column indicate significant differences (p ≤ 0.05).

Sample	Moisture (%)	Crude Protein (%)	Fat (%)	Crude Fibre (%)	Ash (%)	Carbohydrate (%)
A	$8.60^{a} \pm 0.02$	$19.52^{e} \pm 0.03$	$9.71^{e} \pm 0.10$	$0.87^{e} \pm 0.03$	$6.48^{e} \pm 0.02$	$54.75^{a} \pm 0.11$
B	$8.55^{b} \pm 0.03$	$20.92^{d} \pm 0.09$	$10.26^{d} \pm 0.02$	$1.96^{d} \pm 0.02$	$6.90^{d} \pm 0.02$	$52.41^{b} \pm 0.08$
C	$7.86^{c} \pm 0.03$	$22.62^{c} \pm 0.00$	$12.62^{c} \pm 0.02$	$2.44^{c} \pm 0.05$	$9.87^{c} \pm 0.02$	$44.59^{c} \pm 0.06$
D	$6.75^{d} \pm 0.03$	$23.82^{b} \pm 0.02$	$13.41^{b} \pm 0.02$	$3.45^{b} \pm 0.03$	$9.27^{b} \pm 0.01$	$43.30^{d} \pm 0.07$
E	$5.57^{e} \pm 0.07$	$26.85^{a} \pm 0.01$	$13.87^{a} \pm 0.01$	$4.83^{a} \pm 0.02$	$10.63^{a} \pm 0.02$	$38.25^{e} \pm 0.08$
LSD	0.0334	0.0346	0.0400	0.0268	0.0117	0.0684

Mean values with different superscripts in the same column are significantly different ($p \leq 0.05$). **Key:** Sample A = 100% Sorghum flour (Control), Sample B = 5:5:90 (OFSP : Lima bean : Sorghum), Sample C = 5:15:80 (OFSP : Lima bean : Sorghum), Sample D = 10:5:85 (OFSP : Lima bean : Sorghum), Sample E = 5:25:70 (OFSP : Lima bean : Sorghum).

Table 4. Mineral content of gluten-free scones (mg per 100 g, dry weight). Values are mean ± SD (n = 3).

Sample	Sodium (mg/100g)	Magnesium (mg/100g)	Calcium (mg/100g)	Iron (mg/100g)	Phosphorus (mg/100g)
A	$0.757^{c} \pm 0.01$	$0.647^{d} \pm 0.03$	$0.06^{e} \pm 0.02$	$0.61^{e} \pm 0.03$	$0.85^{d} \pm 0.03$
B	$0.840^{bc} \pm 0.02$	$0.740^{c} \pm 0.02$	$1.06^{d} \pm 0.02$	$0.86^{d} \pm 0.02$	$2.45^{c} \pm 0.03$
C	$0.940^{b} \pm 0.03$	$0.727^{c} \pm 0.03$	$2.08^{c} \pm 0.02$	$2.54^{c} \pm 0.02$	$2.71^{b} \pm 0.13$
D	$0.940^{b} \pm 0.02$	$0.850^{b} \pm 0.01$	$2.66^{b} \pm 0.02$	$2.63^{b} \pm 0.01$	$2.86^{ab} \pm 0.02$
E	$2.560^{a} \pm 0.11$	$1.647^{a} \pm 0.03$	$2.83^{a} \pm 0.02$	$2.96^{a} \pm 0.02$	$2.95^{a} \pm 0.03$
LSD	0.0432	0.0200	0.0158	0.0163	0.0513

Mean values with different superscripts in the same column are significantly different ($p \leq 0.05$). **Key:** Sample A = 100% Sorghum flour (Control); Sample B = 5:5:90 (OFSP : Lima bean : Sorghum); Sample C = 5:15:80 (OFSP : Lima bean : Sorghum); Sample D = 10:5:85 (OFSP : Lima bean : Sorghum); Sample E = 5:25:70 (OFSP : Lima bean : Sorghum).

Mineral composition of scones using orange-fleshed sweet potato, lima beans and sorghum flour

The mineral content of the scones is shown in Table 4. All minerals (Na, Mg, Ca, Fe, P) increased significantly ($p \leq 0.05$) in the composite samples compared to the control (sample A).

The sodium content of the samples ranged from 0.757mg/100g for sample A to 2.560mg 100g for sample E. The samples B and C were not significantly different ($p \leq 0.05$). This could be attributed to the proportions of ingredients used during scone blending. Sodium maintains osmotic pressure and helps regulate the body's acid-base balance. Sample E had the highest sodium content, with a value of 2.560mg/100g. Magnesium content of the samples of the scones ranged from 0.647mg/100g for sample A to 1.647mg/100g for sample E. The sample E had the highest magnesium content. The magnesium values showed that the samples were significantly different ($p \leq 0.05$). Magnesium is essential for good health, helping to maintain normal muscle and nerve function, keep the rhythm steady, and support a healthy immune system (Alsaffar, 2011). The increased mineral levels in the composite samples are linked to the inherent richness of legumes and tubers in mineral nutrients (Adebayo-Oyetoro *et al.,* 2017).

Phosphorus content of the samples ranged from 0.85mg/100g for sample A to 2.95mg/100g for sample E. The phosphorus content of the samples was significantly different ($p \leq 0.05$). The phosphorus content of the scone samples was relatively high compared to the report by Peter (2025). Calcium content of the sample ranged from 0.06mg/100g for sample A to 2.83mg/100g for sample E. The values were significantly different ($p \leq 0.05$). The sample E had the highest calcium content. As discussed in previous work (Peter, 2025), calcium is important in the diet because it is necessary for supporting bone formation and growth. Iron content of the scones ranged from 0.61mg/100g for sample A to 2.96mg/100g for sample E. The sample E had the highest iron content, with a value of 2.96mg/100g. The enhanced mineral composition in the fortified scones supports the nutritional objectives of developing functional gluten-free foods, as reported by Mouminah and Althaiban (2025).

Vitamin composition of gluten-free scones

The vitamin A and C contents of the formulated scones are presented in Table 5. Vitamin A (β-carotene) ranged from

Table 5. Vitamin content of gluten-free scones. Vitamin A reported as *β*-carotene (µg per 100 g); Vitamin C in mg per 100 g. Values are mean ± SD.

Sample	Vitamin-A (µg/100 g)	Vitamin-C (mg/100 g)
A	$0.86^{d} \pm 0.10$	$2.66^{b} \pm 0.02$
B	$2.65^{c} \pm 0.10$	$2.68^{b} \pm 0.01$
C	$3.45^{b} \pm 0.20$	$2.48^{b} \pm 0.02$
D	$8.95^{a} \pm 0.20$	$6.55^{a} \pm 0.02$
E	4.26 ± 0.20	$4.64^{b} \pm 0.00$
LSD	0.00208	0.01493

Mean values with different superscripts in the same column are significantly different ($p \leq 0.05$).
Key: Sample A = 100% sorghum flour (Control); Sample B = 5:5:90 (OFSP:lima bean:sorghum); Sample C = 5:15:80; (OFSP:lima bean:sorghum); Sample D = 10:5:85; (OFSP:lima bean:sorghum); Sample E = 5:25:70. (OFSP:lima bean:sorghum).

0.86 µg/100 g (A) to 8.95 µg/100 g (D), while vitamin C ranged from 2.48 mg/100 g (C) to 6.55 mg/100 g (D). The high β-carotene content in samples containing higher OFSP proportions (especially D with 10% OFSP) confirms that orange-fleshed sweet potatoes are a rich source of provitamin A (Rodrigues *et al.,* 2016; Malavi *et al.,* 2022). Vitamin C levels also increased significantly in composite blends, with the highest in sample D. This improvement can be attributed to the contribution of OFSP, which contains natural ascorbic acid. These results agree with Peter (2025), who reported enhanced vitamin profiles in composite foods made with fortified root and tuber crops.

Conclusion and Recommendations

The study showed that high-nutritional gluten-free scone snacks can be made from blends of orange-fleshed sweet potato, lima beans, and sorghum flour, which compare favourably with conventional wheat-flour scones. Sample E, produced from blends of (5:25:70) Orange fleshed sweet potato, lima beans, and sorghum flour, had the highest percentage of protein, fat, ash and crude fibre. The findings show that high-quality, nutritious scone products made mainly from locally sourced raw materials can improve the quality of diets for individuals with coeliac disease, and the incorporation of orange-fleshed sweet potato provides provitamin A, which supports good vision. Therefore, samples E (5.25:70) and D (10.5:25) are recommended due to their high protein and provitamin A content.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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