CHEMICAL COMPOSITION OF BISCUITS PRODUCED FROM ACHA-MALTED SOYBEAN FLOUR BLENDS

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Abstract

This study assessed the effect of malted soybean flour addition on the chemical composition of acha-based biscuits. *Acha* flour was substituted with malted and unmalted soybean flours at four inclusion levels (100:0%, 95:5%, 85:15%, and 75:25%), with 100% wheat flour as a control. The samples were analyzed using standard methods. The results obtained showed that there were significant differences ($P<0.05$) in the proximate composition of the samples. The moisture content of the biscuit samples ranged from 2.44-3.95%, indicating that the biscuit is a low-moisture food product. The samples were also high in ash, protein and fat which ranged from 1.18-2.39%, 8.09-12.88% and 18.71-22.22%, respectively, while the carbohydrate content ranged from 59.67 to 68.16%. As soybean flour inclusion increased, significant increases ($p < 0.05$) were observed in ash, protein, fat, crude fiber, and mineral contents (iron, potassium, phosphorus, magnesium) were observed in the biscuits. Antioxidant properties, including DPPH, FRAP, and ABTS, increased significantly ($p < 0.05$) with higher soybean flour addition. In the biscuit samples produced from *Acha*-malted soybean blends, DPPH increased from 68.79 to 72.84 mg/mL, FRAP (1.90 to 2.93 µmol Fe^{2+}/g), and ABTS (48.02 to 75.70 µmol TE/g). Similarly, biscuit samples produced from *Acha*-unmalted soybean flour blends showed significant increases ($p < 0.05$) in DPPH (71.31 to 75.71 mg/mL), FRAP (0.38 to 2.15 µmol Fe^{2+}/g), and ABTS (44.56 to 76.38 µmol TE/g). Protein digestibility improved significantly ($p < 0.05$) from 140.13% to 178.11%, while starch digestibility improved from 19.62% to 27.79%, with increasing soybean flour inclusion. Amino acid profiles also showed significant improvements ($p < 0.05$), with higher levels of methionine (2.15 g/100g), aspartic acid (8.92 g/100g), and glutamic acid (10.12 g/100g) in the biscuit sample produced from 95% *Acha* and 5% unmalted soybean flour substitutions.

Keywords: Chemical composition, biscuits, acha-malted soybean, flour, blends.

Introduction

Biscuits are convenient ready-to-eat products consumed by people of all ages (Goubgou *et al.,* 2021). They are characterized by low moisture content and are produced from dough that is transformed into appetizing products through baking (Okoye *et al.,* 2022). Their nutritional value can vary depending on the type of cereal used, often being rich in carbohydrates and proteins (Ayo *et al.,* 2019). Traditional biscuit production predominantly relies on wheat flour, which, while versatile, poses challenges for individuals with gluten intolerance or celiac disease (Magaña *et al.,* 2023).

Biscuit production involves combining flour, fat, sugar, and other ingredients to create a dough that is then shaped and baked (Ayo *et al.,* 2024a). The characteristics of the final product are influenced by the choice of flour and other ingredients used. Traditional wheat flour contributes to the structure and texture of biscuits through the formation of gluten, which provides elasticity and gas retention (Mazzola *et al.,* 2024). Wheat (*Triticum aestivum*) has long served as the primary ingredient in baked goods, offering essential nutrients such as carbohydrates (starch), dietary fiber, proteins (gluten), and various vitamins and minerals (Iqbal *et al.,* 2023). The quality and type of wheat influence its baking properties, with gluten being a crucial component for dough elasticity and structure (Chinma *et al.,* 2023a). Gluten, formed from gliadin and glutenin proteins, during hydration and kneading, provides elasticity and strength to the dough. It is essential for the rise and texture of bread and other baked products (Ubbor *et al.,* 2022). Its unique viscoelastic properties allow for diverse processed forms (Zhang *et al.,* 2023b) attributed to the gluten protein-complex formed by grain storage proteins (Mioduszewski and Cieplak, 2022). However, gluten is linked to several immune-mediated disorders, including celiac disease (Zhang *et al.,* 2023b).

The quest for alternative flours and ingredients, such as ancient grains or legume-based flours, presents both an opportunity and a challenge. While these alternatives can provide nutritional benefits and cater to diverse dietary needs, they often require adjustments in formulation and processing techniques to achieve desired baking characteristics (Mason *et al.,* 2021). It is therefore imperative that processing techniques ensure the incorporation of legume such as soybean, to acha, for novel food production is utilized to benefit from their arrays of nutrition for balanced diet. Furthermore, the rise in gluten-related disorders, such as celiac disease and non-celiac gluten sensitivity, poses challenges for the baking industry (Kumar *et al.,* 2023; Sharma *et al.,* 2020). Consumers are increasingly seeking gluten-free alternatives, necessitating the development of suitable substitutes that can mimic wheat's baking properties (Biesiekierski, 2017).

Acha, or fonio (*Digitaria spp*.), is an ancient cereal grain cultivated in West Africa for centuries, which date to about 7,000 years ago and therefore, considered as one of the oldest African cereal crops (Cruz *et al.*, 2016). Valued for its impressive nutritional profile, acha is rich in protein, essential amino acids, dietary fiber, and minerals (Karim, 2022). Despite these benefits and its versatility, acha remains underutilized in modern food production, particularly in baked goods, where wheat flour is the predominant choice.

Acha is particularly notable for its higher protein and fiber contents compared to rice, and its carbohydrate content is greater than that of millet, sorghum, and maize (Ubbor *et al.,* 2022). This gluten-free grain is light and easy to digest, making it suitable for a variety of recipes (Ukim *et al.,* 2021). Additionally, acha's protein fractions exhibit gel filtration profiles similar to durum wheat, indicating its potential in culinary applications (Ayo *et al.,* 2024). The high-water absorption capacity of acha, combined with its pentosan content, allows it to form gels in the presence of oxidizing agents, enhancing its utility in baking (Deriu *et al.,* 2023). Furthermore, acha has a low glycemic index, which may benefit individuals with gluten intolerance and diabetes by minimizing blood sugar spikes (Karim, 2022).

Acha is rich in sulfur-containing amino acids, such as methionine and cysteine, which are often deficient in rice and maize (Ayo et *al.,* 2018; Ukim *et al.,* 2022). These amino acids are present in concentrations higher than those defined by the Food and Agriculture Organization (FAO) protein reference (Charlie *et al.,* 2021). However, acha is limited in essential amino acids like threonine and tryptophan, despite being rich in lysine (Emelike *et al.,* 2021). Blending acha with legumes such as soybean can create a high-quality, cost-effective protein source that includes all essential amino acids in the proper proportions (Emelike *et al.,* 2021).

Soybeans, native to East Asia, are cultivated for their edible beans, which have diverse applications (Song and Ruan, 2019). They are characterized by low carbohydrate content and high protein levels, along with health-promoting compounds that may reduce risks associated with various diseases (Humyra *et al.,* 2019). However, the utilization of soybeans in food formulation is often limited by anti-nutritional factors, beany flavor, and oligosaccharides that can cause digestive discomfort (Aburime *et al.,* 2022). Enhancing soybean quality to improve its nutritional properties is essential. Various methods, such as soaking, malting, boiling, germination and fermentation, have been developed to deactivate these anti-nutritional factors (Samtiya *et al.,* 2022; Humyra *et al.,* 2019).

Soybeans (*Glycine max*) are renowned for their high protein content and beneficial bioactive compounds, such as isoflavones, which contribute to various health benefits (Kim, 2022). The malting process enhances soybean flour by activating enzymes that increase nutrient bioavailability and improve functional characteristics like water retention and emulsification (Adetokunboh, 2022). When incorporated into acha-based products, malted soybean flour can significantly enhance the nutritional and sensory attributes of biscuits—a popular snack food.

Malted soybean flour is rich in proteins, vitamins, and minerals, enhancing functional properties such as solubility and emulsification (Cai *et al.,* 2021). The malting process increases enzyme activity, improving flavor, color, and texture in baked goods (Onwurafor *et al.,* 2020). Therefore, the combination of acha and malted soybean flour could yield biscuits with superior sensory qualities, appealing to health-conscious consumers.

The incorporation of malted soybean flour not only enhances the protein content of biscuits but also improves their functional properties, such as texture and moisture retention (Zhang, 2021). Combining acha with malted soybean flour presents significant potential for developing nutritious, gluten-free biscuits that cater to the growing consumer demand for healthier snack options. By leveraging the nutritional strengths of both ingredients, these products can effectively address dietary needs and preferences, particularly for individuals seeking high-protein alternatives.

This study evaluated the effect of malted soybean flour addition on the chemical composition of acha-based flour biscuits, though the work is limited in the quantification of ingrdients and duration of baking at optimum temperature to achieve optimal conditions.

Materials and Method

Materials

Sources of materials

Acha (*Digitaria exilis*) grains; the creamy coloured type, locally grown was purchased from Jos, Plateau State, while Soybeans (*Glycine max*), baking powder, baking fats, salt and sugar used in the production of the biscuits were purchased from Wukari Main Market, Taraba State, Nigeria.

Preparation of Raw Materials

Acha flour

The acha grains were washed using a stainless-steel bowl to remove stones and adhering dusts. The washed and destoned grains were sun-dried, milled using an attrition milling machine (model R175A: China) to produce acha flour. The powder was sieved (45 µm aperture), packaged in a low-density polyethylene bag and stored under room temperature (Ayo *et al.,* 2018).

Malted soybean flour

Malted soybean flour was produced using the method described by Agu *et al*. (2015). Soybean seeds were cleaned, washed, steeped in water for 48 h at room temperature (32 ^{o}C) before the water was drained and the seeds were spread out on a clean jute bag, moistened and covered with jute bag to allow germination at 28 °C for 72 h with constant hydration and turning of grains. The plumules were removed and the malted soybean was oven dried (50 ºC), cooled (room temperature, 32 ^{o}C), milled (attrition milling machine -model R175A: China), sieved (0.3 mm aperture), and then packaged in a low-density polyethylene and stored at 4 ºC.

Production of malted and unmalted soybean-acha flour blends

The composite flour blends were formulated by combining acha flour with malted soybean flour at 100:0; 95:5; 85:15; and 75:25 and acha-unmalted soybean flour blend at 100:0; 95:5; 85:15; 80:25, respectively, and then used for the biscuit production.

Production of Biscuits

The acha-malted soybean composite flours were screened for their nutritional and antioxidant properties and the samples which had the best qualities, were used for further study. The acha-unmalted soybean flour blend biscuits served as the control. Biscuits were prepared from both malted and un-malted soybean acha flour blends following initial trials guided by the procedure described by Maetens *et al.* (2017). A dough mixer (FP190 Series, Kenwood: Shenzhen, China) was used to prepare the dough by thoroughly mixing the flour (100 g), fat (1 g, margarine), baking powder (3 g), table salt (1.2 g), and water (at flour-water ratio of 2.5: 1) for 8 min. The dough formed was flattened using a pasta maker (Marcato Atlas 150: Italy) and cut into uniform sizes (2.4 cm × 2.4 cm). The dough samples were baked in an oven (Gallenkamp, Widnes, and Cheshire, UK) at a temperature of 190 ^{o}C for 10 min to obtain the biscuits. The biscuits were cooled for 1 h prior to packaging. The average thickness of the baked biscuits was 0.79 mm.

Determination of Chemical Composition of Flour Blend

Proximate composition of flour blends and biscuits

The proximate composition (moisture, crude fat, protein, ash, crude fiber, carbohydrate and energy content) of the sample biscuits from wheat flour, acha flour, acha-malted soybean and acha-unmalted soybean flour blends were analysed using AOAC (2021) method.

Phytochemical Composition

Determination of flavonoid content

The flavonoid content was determined using the method described by Bohm and Kocipal (1994). Five grams (5 g) of the sample was boiled for 30 min under reflux. It was allowed to cool and then filtered through a Whatman No. 42 grade filter paper. A measured volume of the extract was treated with equal volume of ethyl acetate starting with a drop. The flavonoid precipitate was recovered by filtration using a weighed filter paper. The resulting weight difference was recorded as the weight of flavonoid in the sample.

$$\%\,Flavonoid\,Content = \frac{Weight\,of\,residue}{Weight\,of\,Sample\,Ta\ker}\,x\,100 \quad (9)$$

Determination of carotenoid content

The carotenoids content was determined according to the method described by Krishnaiah *et al*. (2009). A measured weight of biscuit sample was homogenized in methanol using a laboratory blender. A 1:10 (1%) mixture was used. The homogenate was filtered to obtain the initial crude extract, 20 ml of the other was added to the filtrate and mixed well and then treated with 20 ml of distilled water in a separating funnel. The ether layer was recovered and evaporated to dryness at low temperature (50 ^{o}C) in a vacuum dessicator. The dry extract was then saponified with 20 ml of ethanoic potassium hydroxide and left over in a dark cupboard. The next day, the carotenoid was taken up in 20 ml of ether and then washed with two portions of 20 ml distilled water. The carotenoid extract (ether layer) was dried in a dessicator, treated with light petroleum (petroleum spirit) and then allowed to stand overnight in a freezer (-10 ^{o}C). The precipitated steroid was removed by centrifugation after 12 h and the carotenoid extract was evaporated to dryness in a weighed evaporation dish, cooled in a dessicator and weighed. The weight of carotenoid was determined and expressed as a percentage of the sample weight.

$$\%\,Carotenoid\,Content = \frac{Weight\,of\,sample}{Weight\,of\,sample\,ta\ker}\,x\,100 \quad (10)$$

Determination of total phenolic content (TPC)

Total phenolic content (TPC) was estimated using the Folin–Ciocalteau (FC) method, using gallic acid as the standard (Singleton *et al.,* 1999). Extracts were prepared in aqueous methanol (80%) containing 1% HCl. Extraction was carried out for 4 h by mixing 2 g sample with 20 ml acidic methanol, then centrifuged for 10 min, and collected the supernatant. Exactly 1 ml of the extract was taken in a test tube, added 5 ml of FC reagent (diluted 10- fold), and then 4 ml of 7% Na_2CO_3 was added after resting for 5 min. Samples were incubated in the dark for 90 min, and absorbance was measured at 765 nm. Results were expressed as mg GAE/ 100 g dry matter.

Determination of Minerals Content of Biscuit Samples

Determination of iron

Iron was determined using Poitevin (2016) method. Phenanthroline solution was prepared by dissolving 100 mg 1,10-phenanthroline molybdate in 100 ml distilled water by stirring and heating to 80 ^{o}C. Hydroxylamine solution was prepared by dissolving 10 g in 100 ml of distilled water, while ammonium acetate buffer solution was prepared by dissolving 250 g in 150 ml distilled water. Exactly 5 ml of the digested sample was added in a test-tube. Then, 3 ml of phenanthroline solution and 2 ml of HCl were added. Hydroxylamine solution (1 ml) was added to the mixture and boiled in a steam bath at 600 ^{o}C for 2 mins. Then, 9 ml of ammonium acetate buffer solution was added and 35 ml diluted to 50 ml with water. The absorbance was taken at 510 nm. Calibration curve was prepared by pipetting 2, 4-, 6-, 8-, and 10-ml standard iron solution into 100 ml volumetric flasks to prepare a solution of known concentrations. The curve obtained was used to read off the value of iron.

Determination of potassium and posphorous

The potassium in the sample was determined by flame photometry method using an instrument called flame photometer. Phosphorus in the sample was determined by the vanadomohybdate (yellow) spectrometry (AOAC, 2000).

Determination of magnesium

The magnesium content of the sample was investigated using atomic absorption spectrophotometric method (Poitevin, 2016). Five hundred milligram (500 mg) of the sample was weighed into a digestion flask and 10 ml of nitric acid and 10 ml of HCl was added. The mixture was digested for 10 min. The digested mixture was filtered using No. 1 Whatman filter paper. The filtrate was made up to 50 ml with distilled water. An aliquot was transferred to the Auto-analyser for total phosphorus analysis at 420 nm. The left-over digest was used to determine the other elements using the Atomic Absorption Spectrophotometer (Perkin Elmer, model 402: USA)

Determination of Vitamins

Determination of vitamin B_1 (Thiamine) and B_2 (Riboflavin)

The thiamin and riboflavin content of the samples were determined using the photometric method of AOAC (2021) procedure.

Statistical Analysis

All the analyses were conducted in triplicate in completely randomized design. The data was subjected to analysis of variance using Statistical Package for Social Science for ANOVA (SPSS) software version 23.0. Duncan means separation was tested using least significant difference (LSD) test. The significance was accepted at p<0.05.

Results and Discussion

Chemical composition of Biscuit Samples from processed Acha-Soybean Flour

Proximate Composition of Biscuit Samples

The effect of added malted and un-malted soybean flour on the proximate composition of biscuits are as shown in Table 1. There were significant differences ($p < 0.05$) in moisture, ash, crude protein, fat, crude fibre and carbohydrate contents of the biscuit samples. The moisture, ash, crude protein, fat, and crude fibre contents increased from 2.44–3.02%, 1.30–1.91%, 8.59–12.88%, 19.36–22.22%, and 0.16–0.30%, respectively, in acha–malted soybean biscuits. Similarly, these components increased from 3.20–3.81%, 1.19–2.39%, 8.77–12.00%, 18.93–21.61%, and 0.16–0.30% in acha–unmalted soybean biscuits with increasing levels of malted and unmalted soybean flour. Contrastingly, the carbohydrate content decreased from 68.16 to 59.67% and from 67.70 to 60.90% with increasing incorporation of malted and unmalted soybean flours, respectively. The results indicate that adding malted and un-malted soybean flours to biscuits increases the content of moisture, ash, crude protein, fat, and crude fiber, while the carbohydrate content decreased. This agrees with the findings of Keyata *et al.* (2021) who noted similar benefits in baked goods with addition of soybeans.

The increase in moisture content of the biscuits from 2.44% to 3.02% with the addition of malted soybean flours and from 3.02% to 3.81% with the addition of un-malted soybean flours, indicates better water retention in the product. Moisture is important for the texture, freshness, and shelf-life of baked goods. More moisture makes biscuits softer and tastier, and more appealing to consumers (Ravindra, 2021). According to Chinma *et al.* (2021), the moisture values were within the safe limit (≤10%) for the storage of flour products. A 2-tailed t-test comparison (-17.232; $\alpha = 0.003$) carried out on the samples showed that there was a significant difference ($p<0.05$) between the moisture content of the samples with malted and unmalted soybean inclusion. Moreso, the correlation of the moisture content of the biscuit samples with malted and unmalted soybean addition revealed a correlation coeffient of 0.979 ($\alpha = 0.131$) which was an indication that there was a 95.84% chance that such differences could be due to treatment methods used in the flour preparations. However, the 100% wheat flour biscuit had the highest moisture content of 3.95% but the 100% acha flour biscuit sample had 2.91% moisture content.

The ash content increased from 1.30 - 1.91% and 1.19 – 2.39% with increased levels of both malted and un-malted soybean flour addition, respectively. The values agreed with results of other research studies (Okereke *et al.,* 2021; Akubor *et al.,* 2023). The increase in ash content of the biscuit samples could be due to the higher ash content of the soybean flour than in the acha, as soybean had been reported to contain an appropriate quantity of minerals and fat (Okereke and Banigo, 2021). The ash content in thes samples represents the total mineral content of the biscuits. The soybean flour is rich in essential minerals such as calcium, magnesium, and iron, contributing to the increased ash content. These minerals are vital for various bodily functions, including bone health, muscle function, and oxygen transport (Awuchi *et al.,* 2020). Although there were differences in the ash content of the biscuit samples, a t-test (t-test = 0.109; $\alpha = 0.923$) of the biscuits prepared with malted and unmalted soybean flour addition indicates no significant difference ($p>0.05$), with a correlation coefficient of 0.807, which implies 65.12% ($\alpha = 0.402$) assurance that the significant differences observed in the individual product's ash content was due to chance effect. Therefore, biscuit producers whose intention was to produce biscuits with improved minerals could use resort to the use of unmalted soybean inclusion as malting could add to cost of the product.

A significant difference ($P<0.05$) was observed in the protein content of the biscuit samples. The crude protein content increased from 8.59% to 12.88%, and 8.77% to 12.00% following the increase in the level of the malted and unmalted soybean inclusion, respectively, reflecting the high protein content of soybean flour, with the malted soybean flour contributing more to the increased protein content than the unmalted soybean flour. Ikegwu *et al.* (2021) observed that malting had significant ($p<0.05$) influence on the protein content of grains. The protein content of the different treatments was not significant (correlation coefficient, 0.945; $\alpha = 0.213$), which shows 89.30% assurance that there was a relationship between the processing methods, although the influence of the relationship for the two treatments (malted and unmalted soybean substitution) on the protein content of the biscuit samples was not significant ($p>0.05$) (2-tailed t-test = -0.35; $\alpha = 0.975$). Protein plays a crucial role in building and repairing tissues, producing enzymes and hormones, and supporting immune function. The enhanced protein content in these biscuits contributes to meeting dietary protein requirements, particularly beneficial in regions where protein malnutrition is a concern. The inclusion of soybean flour helps create a more protein-rich product which aligns with the findings of Gulkirpik (2022) of addressing protein-energy malnutrition and promoting nutritional adequacy.

Table 1: Proximate composition of acha-malted and acha-un-malted soybean flour biscuits

Sample Blend (%) WF:AF:UMSF:MSF	Sample Code	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Crude Fibre (%)	CHO (g)
100:0:0:0	A	3.95^{h}±0.06	2.05^{c}±0.06	10.37^{e}±0.00	18.71^{a}±0.02	0.72^{e}±0.02	64.21^{d}±0.00
0:100:0:0	B	2.91^{b}±0.02	1.18^{a}±0.02	8.09^{a}±0.03	19.14^{c}±0.00	0.80^{f}±0.01	67.89^{g}±0.03
0:95:0:5	C	2.44^{a}±0.00	1.30^{b}±0.01	8.59^{b}±0.06	19.36^{d}±0.02	0.16^{a}±0.02	68.16^{h}±0.04
0:85:0:15	D	3.08^{d}±0.03	1.67^{a}±0.04	10.10^{d}±0.01	20.88^{e}±0.02	0.40^{d}±0.00	63.89^{c}±0.02
0:75:0:25	E	3.02^{c}±0.03	1.91^{a}±0.03	12.88^{h}±0.02	22.22^{g}±0.00	0.30^{c}±0.01	59.67^{a}±0.02
0:95:5:0	F	3.20^{e}±0.03	1.19^{a}±0.03	8.77^{c}±0.02	18.93^{b}±0.01	0.16^{a}±0.01	67.70^{f}±0.02
0:85:15:0	G	3.73^{f}±0.00	1.21^{a}±0.01	10.85^{f}±0.03	19.73^{d}±0.02	0.21^{b}±0.02	64.28^{e}±0.00
0:75:25:0	H	3.81^{g}±0.04	2.39^{d}±0.02	12.00^{g}±0.04	21.61^{f}±0.02	0.30^{c}±0.00	60.90^{a}±0.02

Values are presented as means ± SD. Values with different superscript within the same column are significantly different (p<0.05). Key: A = 100% WF, B =100% AF, C = 95% AF; 5% MSF, D = 85% AF; 15% MSF, E = 75% AF; 25% MSF, F = 95% AF; 5% UMSF. G = 85% AF; 15% UMSF, H = 75% AF; 25% UMSF Where WF = Wheat Flour, AF = Acha Flour, MSF = Malted Soybean Flour and UMSF = Un-Malted Soybean Flour

There were significant differences (P<0.05) in the fat content of the biscuit. The fat content increased from 19.36% to 22.22% for samples with malted soybean and from 18.93% to 21.61% for biscuit samples with the substituted un-malted soybean samples. However, it was observed that even though there was relationship (p<0.05) between the malted and malted soybean substitution in the biscuit samples (correlation = 0.965; α = 0.165), such relationship was not significant (p>0.05) as further buttressed by the 2-tailed t-test (x = 3.374; α = 0.078). Therefor, the significant variations (p<0.05) in the fat content of the samples arising from substitution of the malted and unmalted soybean flours in the biscuit samples could be due to level of substitution of the soybean and not due to treatment effect. The increase in fat content due to soybean substitution might be due to the natural oils in soybeans. Fat is an essential macronutrient that provides energy, supports cell growth, and aids in the absorption of fat-soluble vitamins as recorded by Ayo *et al.* (2018) in a related study. According to WHO guidelines, fats should make up 20-35% of total energy intake, with a focus on unsaturated fats, while limiting saturated fats and trans-fats. The fat content in these biscuits, derived mainly from unsaturated sources in soybeans, contributes to a healthier fat profile, aligning with WHO (2023) recommendations for reducing the risk of chronic diseases associated with high saturated fat intake.

The crude fiber content increased from 0.16% to 0.30% for biscuit samples substituted with malted soybean flour, while the samples substituted with unmalted soybean flour increased from 0.16% to 0.40%. The increase in the fibre content of the samples were significant (p<0.05). However, the biscuit samples substituted with soybean were observed to rank low in fibre content when compared to either the 100% wheat or acha flours biscuit. It is important to note that the sample with 100% acha flour had the highest fibre content which posits it a a grain for functional food development. However, the there were no significant (p>0.05) relationship between the malted and unmalted soybean flour in relation to the fibre content of the biscuit samples (correlation = 0.440; α = 0.710). This assertion is further supported by the two-tailed t-test (X = 1.00; α = 0.423) which indicated that the fibre content had no positive significant (p>0.05) contribution to the fibre content of the biscuit samplesDietary fiber is important for maintaining digestive health, regulating blood sugar levels, and reducing the risk of cardiovascular diseases (Alahmari, 2024). Recent studies have shown that fibre could be used for functional food formulation (Ikegwu *et al.,* 2023).

The results also indicated significant variations (p<0.05) in the carbohydrate content of the biscuit samples, ranging from 59.67% to 68.16%. It was observed that there was significant (p<0.05) reduction in the carbohydrate content of the biscuit samples with incremental susbtitution of either malted or unmalted soybean flour to acha flour. The reduction in the carbohydrate content ranged from 67.70 to 60.90% when malted soybean flour was substituted to acha flour in biscuit baking and 68.16 to 59.67% when unmalted soybean flour was substituted in the biscuit samples. Furthermore, the 5% substitution of unmalted soybean flour led to significant (p<0.05) increase in the carbohydrate content of the biscuit sample before reduction was observed, which differed from the trend observed in the biscuit samples with malted soybean substitution. The increase could be adduced to either instrumental or human error in the investigation. The decrease in carbohydrates from 68.16 to 59.67% with the substitution of malted soybean flour to acha flour could be due to the use of the carbohydrate in soybean as energy source which converts carbhydrates to simple sugars like maltose, maltodextrines and glucose after the activation of α-amylase and β-amylase enzymes.during malting and the replacement of more carbohydrate-rich ingredients with protein and fat-rich soybean flour. Carbohydrates are a primary energy source, and WHO (2023) recommends that they should provide 55-75% of total energy intake.

From the results, sample E (75% Acha, 25% MSF) tends to be nutritionally superior, especially in terms of protein (12.88g) and fat (22.22g) content, making it the best choice for high-energy, nutrient-dense biscuits. It also provides a balanced amount of fiber and carbohydrates.

Mineral compositions of the acha- malted soybean flour blend biscuits

The mineral composition of the biscuits from malted and un-malted soybean flours to acha flour are as presented in Table 2. There were significant differences (p < 0.05) observed in the iron, potassium, phosphorus and magnesium contents of the biscuit samples. The iron, potassium, phosphorus and magnesium contents of the biscuit samples ranged from 0 - 18.00 ppm, 2445.00 – 4695.00 ppm, 608.80 – 1221.50 ppm and 98.81 – 105.42 ppm for acha-malted biscuit samples, while that of acha-ummalted biscuit samples are 8.05- 10.00 ppm, 2732 – 4275.00 ppm, 921.1 – 1686.40 ppm and 108.57-128.03 ppm, respectively. A significant increase ($p < 0.05$) was observed in the iron, potassium, phosphorus and magnesium contents with increase in gradual substitution of malted and un-malted soybean flours.

The results showed that Fe was not determined in the wheat flour and acha flours with 5% and 15% unmalted soybean substitution which could be due to the level of sensitivity of instrumental analysis or the result of human error since 10 ppm of iron content was found in the 100% acha flour. According to Anila-Kumari *et al.* (2016) and Platel *et al.* (2010), malting increased the bioavailability of total iron in millet and soybean flours, wheat, and barley.

TABLE 2: Mineral compositions of the acha-malted soybean flour blend biscuit

Sample Blend (%) WF:AF:UMSF:MSF	Sample Code	Fe (ppm)	K (ppm)	P (ppm)	Mg (ppm)
100:0:0:0	A	ND	$4155.00^{d}\pm0.00$	$1658.80^{g}\pm0.00$	$98.16^{a}\pm0.05$
0:100:0:0	B	$10.00^{d}\pm0.00$	$2325.00^{a}\pm0.00$	$780.90^{b}\pm0.00$	$123.53^{h}\pm0.28$
0:95:0:5	C	ND	$2445.00^{b}\pm0.00$	$608.80^{a}\pm0.14$	$98.81^{b}\pm0.09$
0:85:0:15	D	ND	$4681.00^{g}\pm1.41$	$1179.10^{e}\pm0.00$	$102.55^{c}\pm0.20$
0:75:0:25	E	$18.00^{e}\pm0.00$	$4695.00^{h}\pm0.00$	$1221.50^{f}\pm0.00$	$105.42^{d}\pm0.27$
0:95:5:0	F	$8.05^{c}\pm0.01$	$2732.00^{c}\pm2.82$	$921.10^{c}\pm0.71$	$108.57^{f}\pm0.15$
0:85:15:0	G	$8.40^{b}\pm0.00$	$4321.00^{f}\pm1.41$	$1110.50^{d}\pm0.02$	$118.44^{g}\pm0.14$
0:75:25:0	H	$10.00^{a}\pm0.00$	$4275.00^{e}\pm0.00$	$1686.40^{h}\pm3.47$	$128.03^{a}\pm0.02$

Values are presented as means ± SD. Values with different superscript within the same column are significantly different (p<0.05). Key: A = 100% WF, B =100% AF, C = 95% AF; 5% MSF, D = 85% AF; 15% MSF, E = 75% AF; 25% MSF, F = 95% AF; 5% UMSF.G = 85% AF; 15% UMSF, H = 75% AF; 25% UMSF Where WF = Wheat Flour, AF = Acha Flour, MSF = Malted Soybean Flour and UMSF = Un-Malted Soybean Flour. ND = Not determined.

Iron is essential for the formation of hemoglobin which is crucial for oxygen transport and energy metabolism (Zeidan *et al.,* 2024). The iron content of biscuit samples from acha-malted soybean and acha-unmalted soybean flour blends showed significant variation from 0.00 to 18.00 ppm and 8.05 to 10.00 ppm, respectively. Sample E (75% acha flour and 25% malted soybean flour) had the highest iron content, making it the best choice for those needing to boost their iron intake, such as individuals with anemia or iron deficiency. This analysis agrees with the research of Bathla and Arora (2022) who noted that higher iron content supports enhanced prevention of iron deficiency anemia and supports increased iron bio-availability due to the malting process. This is beneficial for improving hemoglobin levels and overall energy (Anitha *et al.,* 2021). The WHO recommends that adults should consume around 8-18 mg of iron per day (WHO, 2020). However, doses higher than 20 mg/day could cause stomache upset in individuals and may result to constipation and blackened stools (Beutter and Whales, 2006; Ikegwu and Iwouno, 2015).

The potassium content of biscuit samples from substituted acha-malted and acha-un-malted soybeanflour blends varied significantly from 2445.00 to 4695.00 ppm and 2732.00 to 4275.00 ppm, respectively. There was higher potassium content in the malted acha-soybean biscuits (2445.00 – 4695.00 ppm) compared to acha-un-malted biscuit (2732.00 – 4275.00 ppm) samples which could be attributed to the effects of the malting process on the nutritional profile of the biscuits (Agu *et al.,* 2020). El-Gohery (2021) noted that through the reduction of phytic acid, which can bind minerals and impede their absorption, malting boosts the bio-availability of nutrients. Consequently, this process can lead to a higher potassium level in biscuit products. Potassium is crucial for maintaining proper heart function, muscle contractions, and nerve transmissions (Ayo *et al.,* 2024). Effect of Potassium in reduction of blood pressure had been reported (Ikegwu and Iwouno, 2015).

The phosphorus content of biscuit samples from both acha-malted and acha-un-malted soybean flour blends varied significantly from 608.80 to 1221.50 ppm and 921.10 – 1686.40 ppm, respectively. The mineral content across the samples displayed a range of phosphorus levels, with the acha flour biscuit (B; 100% Acha Flour) showing 780.90 ppm. In contrast, the inclusion of malted soybean flour insamples D and E (85% Acha Flour and 15% Malted Soybean Flour; 75% Acha Flour and 25% Malted Soybean Flour) resulted in higher phosphorus content (1179.10 ppm and 1221.50 ppm, respectively). This increase highlights the beneficial impact of malted soybean flour on the phosphorus content of the blends, supporting findings by Etiosa *et al.* (2017) regarding the mineral richness of soybean flour. Phosphorus is essential for bone health and energy metabolism (Serna and Bergwitz, 2020).

Sample H (75% acha flour, 25% unmalted soybean flour) showed significantly higher phosphorus levels of 1686.40 ppm than Sample D (85% acha flour, 15% malted soybean flour) and Sample E (75% acha flour, 25% malted soybean flour). The higher phosphorus content in Sample H (75% AF + 25% UMSF) was likely due to the retention of natural phosphorus in unmalted soybeans (Nafula *et al.,* 2022), whereas the malting process might result in some loss of total phosphorus or changes in its form, making it less concentrated in malted soybean flour. Additionally, the phytic acid content in unmalted soybeans keeps more phosphorus locked in the flour, leading to higher total phosphorus values. Udeh *et al.* (2018) postulated the phosphorous content of malted grains is time-dependent as significant reduction ($p<0.05$) was observed in malted finger millet after 24 h, but increased within the next 96 h. Contrastingly, the same study posited that the phosphorous content of sorghum grain increased within 24 h during malting. It could be concluded that the level of phosphorous content in food grains is dependent on the duration during malting process.

In the acha-malted soybean, magnesium content ranged from 98.81 to 105.42 ppm, indicating that malted soybean is a moderate source of the mineral. Malting can enhance magnesium bioavailability by reducing antinutritional factors like phytic acid, which inhibits mineral absorption, although some magnesium loss can occur during the process (Rousseau *et al.,* 2020; Burgos and Armada, 2020). The acha-unmalted soybean biscuit samples, in contrast, contains higher magnesium levels (98.03 to 118.91 ppm), potentially contributing more significantly to daily intake. However, the presence of antinutritional factors in the unmalted soybean flour might impair magnesium absorption (Onwurafor *et al.,* 2020). It is important to note that the baking temperature could favourably destroy the antinutrients thereby making the magnesium bioavailable in the biscuit samples. Magnesium is an essential mineral involved in various physiological functions, including bone health, cardiovascular function, and metabolic processes (Fatima *et al.,* 2024). It plays a critical role in bone mineralization and density, assists in regulating calcium and vitamin D levels, and helps prevent osteoporosis and bone fragility (Wang *et al.,* 2025).

Both malted and unmalted soybean flours can contribute to meeting daily magnesium requirements. The effectiveness in providing bioavailable magnesium may vary, with malted flour potentially offering better absorption despite its lower total magnesium content. Ensuring adequate magnesium intake is crucial for maintaining health and meeting WHO guidelines.

3.3.3 Vitamin content of the acha- malted soybean flour blend biscuits

Table 3 presents the results of vitamin composition of biscuit samples from Acha-malted soybean and Acha-um-malted soybean Flour blends. The susbtitution of malted soybean flour consistently enhanced vitamin B_1 (thiamine) and B_2 (riboflavin) levels. The sample E, with 25% malted soybean flour, displayed the highest concentrations of both vitamins in soybean-containing samples, with vitamin B_1 content at (0.06 ppm) and vitamin B_2 at (0.07 ppm). These results suggest that incorporating both malted and unmalted soybean flour can enrich vitamin B_1 and B_2 content in biscuits, potentially enhancing their nutritional value, although the unmalted soybean flour contributed mor to the vitamin B_1 content compared to the malted soybean flour.

Table 3: Vitamin content biscuit samples from acha- malted soybean and acha-unmalted soybean flour blends

Sample Blend (%) WF:AF:UMSF:MSF	Sample Code	Vitamin b 1 (mg)	Vitamin b 2 (mg)	Vitamin b 1 (mg)	Vitamin b 2 (mg)
100:0:0:0	A	$0.04^{a}\pm0.00$	$0.10^{e}\pm0.01$	$0.86^{f}\pm0.02$	$0.38^{e}\pm0.03$
0:100:0:0	B	$0.03^{a}\pm0.00$	$0.03^{a}\pm0.00$	$0.28^{a}\pm0.02$	$0.12^{a}\pm0.00$
0:95:0:5	C	$0.03^{a}\pm0.00$	$0.06^{c}\pm0.00$	$0.54^{c}\pm0.00$	$0.24^{c}\pm0.00$
0:85:0:15	D	$0.05^{a}\pm0.00$	$0.06^{c}\pm0.00$	$0.63^{d}\pm0.03$	$0.24^{c}\pm0.00$
0:75:0:25	E	$0.06^{a}\pm0.00$	$0.07^{d}\pm0.00$	$0.75^{e}\pm0.01$	$0.28^{d}\pm0.00$
0:95:5:0	F	$0.02^{a}\pm0.00$	$0.06^{c}\pm0.00$	$0.52^{bc}\pm0.01$	$0.24^{c}\pm0.00$
0:85:15:0	G	$0.03^{a}\pm0.00$	$0.04^{b}\pm0.00$	$0.50^{b}\pm0.02$	$0.16^{b}\pm0.00$
0:75:25:0	H	$0.05^{a}\pm0.00$	$0.06^{c}\pm0.00$	$0.64^{d}\pm0.01$	$0.24^{c}\pm0.00$

Values are presented as means ± SD. Values with different superscript within the same column are significantly different (p<0.05). Key: A = 100% WF, B =100% AF, C = 95% AF; 5% MSF, D = 85% AF; 15% MSF, E = 75% AF; 25% MSF, F = 95% AF; 5% UMSF. G = 85% AF; 15% UMSF, H = 75% AF; 25% UMSF Where WF = Wheat Flour, AF = Acha Flour, MSF = Malted Soybean Flour and UMSF = Un-Malted Soybean Flour

Vitamins B_1 and B_2 are essential for energy metabolism and cellular function (Hrubša *et al.,* 2022). Vitamin B_1 (Thiamine) plays a crucial role in carbohydrate metabolism, while Vitamin B_2 (Riboflavin) is vital for the metabolism of fats, proteins, and carbohydrates. Insufficient intake of these vitamins can lead to metabolic disorders (Oladiji *et al.,* 2024).

The Table 3 revealed that Sample E, which contains 25% unmalted soybean flour had the highest concentrations of vitamins B_1 (0.06) and B2 (0.070) among all samples. This suggests that incorporating unmalted soybean flour significantly boosts the content of these essential vitamins. Other researchers had observed that the level of B-vitamins in malted grains depends on the duration of malting (Ochanda *et al.,* 2010). On the other hand, Onwurafo *et al.* (2020) observed that malting improves thiamine (vitamin B_1) levels in legumes, and Moyo (2024) who reported that malting enhances the bioavailability of thiamine in soybean products (Nkhata *et al.,* 2018; Yousaf *et al.,* 2021). The increased vitamin content in Sample E (75% Acha Flour; 25% Malted Soybean Flour) can be attributed to the malting process, which activates enzymes that convert stored nutrients into more accessible forms, thereby enhancing the product's nutritional profile. Furthermore, studies by other researchers confirm that malting effectively increases vitamin B_2 levels in legumes (Baskota, 2019; Usman, 2021). According to the World Health Organization, vitamins B_1 and B_2 are crucial for energy metabolism and overall health (WHO, 2023). The observed increases in these vitamins in malted soybean flour supports WHO guidelines, which emphasize the importance of optimizing nutrient content in food through processing to meet dietary needs and enhance health.

3.3.4 Phytochemical properties of the acha- malted soybean flour blend biscuits

The Table 4 provides the phytochemical properties of biscuits formulated from wheat, Acha (*Digitaria exilis*), acha-malted soybean, and acha-un-malted soybean flours. The phytochemical compounds analyzed included flavonoids, phenols, and carotenoids. The result shows that flavonoid increased from 7.94 to 12.09 mg/g and 4.07 to 16.39 mg/g, and phenolic content ranged from 41.39 to 57.03 mg/g and 36.75 to 49.79 mg/g, for biscuit samples from acha-malted soybean, and acha-un-malted soybean flour blends, respectively. The carotenoids showed no significant difference (p>0.05), with values ranging from 0.19 to 0.24 mg/g and 0.23 to 0.52 mg/g for biscuit samples from acha-malted soybean, and acha-un-malted soybean flour blends, respectively.

Table 4: Phytochemical properties of the acha- malted soybean flour blend biscuits

Sample Blend (%) WF:AF:UMSF:MSF	Sample Code	Flavonoid (mg/g)	Phenol (mg/g)	Carotenoid (mg/g)
100:0:0:0	A	$4.39^{ab}\pm1.13$	$32.57^{b}\pm0.13$	$0.21^{ab}\pm0.01$
0:100:0:0	B	$4.88^{ab}\pm0.42$	$27.03^{a}\pm0.71$	$0.21^{ab}\pm0.01$
0:95:0:5	C	$7.94^{bc}\pm0.00$	$41.39^{d}\pm0.20$	$0.27^{b}\pm0.00$
0:85:0:15	D	$11.16^{cd}\pm0.56$	$47.67^{e}\pm0.71$	$0.19^{a}\pm0.04$
0:75:0:25	E	$12.09^{a}\pm0.42$	$57.03^{a}\pm0.83$	$0.24^{ab}\pm0.04$
0:95:5:0	F	$4.07^{ab}\pm5.19$	$36.75^{ec}\pm0.83$	$0.23^{ab}\pm0.07$
0:85:15:0	G	$14.06^{de}\pm2.40$	$47.67^{e}\pm1.53$	$0.19^{a}\pm0.00$
0:75:25:0	H	$16.39^{e}\pm1.27$	$49.79^{e}\pm2.11$	$0.52^{c}\pm0.01$

Values are presented as means ± SD. Values with different superscript within the same column are significantly different (p<0.05). Key: A = 100% WF, B =100% AF, C = 95% AF; 5% MSF, D = 85% AF; 15% MSF, E = 75% AF; 25% MSF, F = 95% AF; 5% UMSF. G = 85% AF; 15% UMSF, H = 75% AF; 25% UMSF Where WF = Wheat Flour, AF = Acha Flour, MSF = Malted Soybean Flour and UMSF = Un-Malted Soybean Flour

Flavonoids and phenolic compounds are known for their antioxidant properties and potential health benefits, including anti-inflammatory and anti-cancer effects (Griffiths, 2016). Research by Zani *et al. (*2022) highlights the role of these compounds in combating oxidative stress and their relevance in functional foods. The increase in flavonoid and phenolic content in biscuits formulated with higher proportions of Acha Flour and malted soybean was indicative of their rich phytochemical profile.

The sample E (75% Acha Flour, 25% malted soybean flour) showed a significant increase (P<0.05) in both flavonoids (12.09 mg/g) and phenols (57.03 mg/g), suggesting that the inclusion of malted soybean flour enhances the nutritional value of the biscuits (Ayo *et al.,* 2014; Azeez *et al.,* 2024). Ashaolu *et al.* (2023) stated how the fermentation process in malting increases bioactive compounds in legumes. Phenolic compounds, known for their antioxidant and anti-inflammatory effects, increased from 41.39 to 57.03 mg/g and from 36.75 to 49.79 mg/g in biscuit samples from acha-malted and acha-un-malted soybean flour blends, respectively. This increase supports the findings of Nkhata *et al.* (2018) and Asuk *et al.* (2023) who noted that malting improves the phenolic content in soybean products by converting bound phenolics to more bioavailable forms.

In this study, significant differences (p < 0.05) were observed in the carotenoid content of biscuit samples from both acha-malted and acha-un-malted soybean flour blends. The carotenoid contents varied from 0.19 to 0.52 mg/g with Sample H (75% acha flour and 25% un-malted soybean flour) exhibiting the highest value at 0.52 mg/g. This value was significantly different (p < 0.05) from all other samples, indicating the profound impact of un-malted soybean addition at higher inclusion levels. Conversely, the lowest carotenoid content was recorded in Sample D and G (0.19 mg/g and 0.19 mg/g, respectively), which both contained 15% of either malted or un-malted soybean flour. These findings suggest a non-linear relationship between soybean flour inclusion and carotenoid content, potentially influenced by the processing method (malting) and concentration used (Johnson *et al.,* 2023).

Interestingly, Sample C, which contained only 5% malted soybean flour, showed a carotenoid content of 0.27 mg/g, higher than several other formulations with greater soybean content. This may indicate that lower levels of malted soybean may retain or enhance carotenoid stability better than at higher levels, where processing losses could become more pronounced.

Comparatively, Samples A and B, which were control samples made from 100% wheat flour and 100% acha flour respectively, had carotenoid contents of 0.21 mg/g, not significantly different (p>0.05) from each other, but lower than most of the composite blends. This reinforces the role of soybean, especially in its un-malted form, in enhancing carotenoid content in cereal-based formulations.

These findings align with those of Ture and Bekele (2024), who reported carotenoid contents ranging between 0.12–0.35 mg/g in soy-enriched biscuits. Similarly, Sanni-Olayiwola *et al.* (2014) reported carotenoid values between 0.09 to 0.27 mg/g in acha-based composite products. The relatively higher value obtained in this study, particularly in Sample H, indicates a nutritionally superior product and could be attributed to the higher proportion of un-malted soybean flour, which is known to be rich in natural pigments and less exposed to heat degradation compared to malted soybeans.

It is also worth noting that malting, while beneficial in enhancing certain nutrients and digestibility, may lead to degradation of heat-sensitive compounds such as carotenoids (Latha-Ravi and Rana, 2024). This explains why un-malted soybean blends (e.g., Sample H) outperformed their malted counterparts (Sample E: 0.24 m/mg) in terms of carotenoid retention.

In conclusion, the variation in carotenoid content among the biscuit samples was significantly influenced by the type and level of soybean flour incorporation. The un-malted soybean flour at higher substitution levels (25%) resulted in the most notable enhancement of carotenoid content, highlighting its potential in developing functional and nutrient-enriched biscuits. This underscores the value of unprocessed legumes in food fortification strategies aimed at combating micronutrient deficiencies. Carotenoids, which contribute to the color of many fruits and vegetables, are important for vision, skin health, and overall immunity (Meléndez-Martínez, 2019).

The phytochemical composition observed in these biscuits, especially in samples with higher Acha and soybean content, aligns with WHO's guidelines on enhancing dietary diversity and nutrient intake. The presence of flavonoids, phenols, and carotenoids in these products could contribute positively to public health by offering an alternative source of essential nutrients.

Amino acid profile

The amino acid profile for Samples A to H is shown in Figure 1. It shows the concentrations of various essential and non-essential amino acids and reveals variations which have implications for their nutritional value.

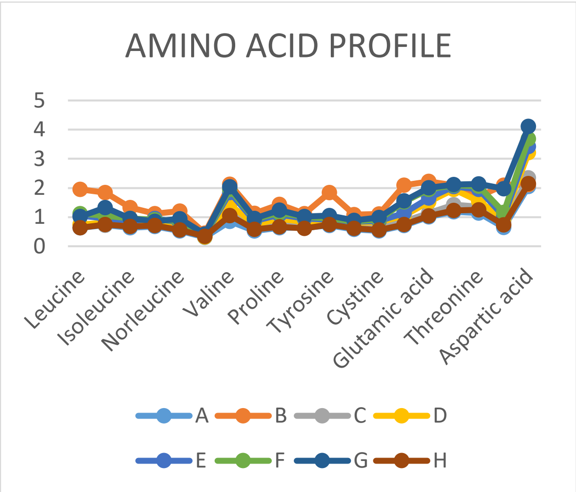

Figure.1. Amino Acid Profile

Sample A (100% wheat flour) had high levels of most amino acids, particularly Valine, Alanine, Glutamic acid, and Aspartic acid, making it potentially valuable for nutritional purposes (Chiedu *et al.,* 2023). Sample B (100% acha flour) had lower overall concentrations, with Aspartic acid being the highest. The sample C (95% acha flour; 5% malted soybean flour) maintained a balanced profile, especially for Aspartic acid and Glycine, which supports its nutritional benefits (Plygun *et al.,* 2020). Sample D (85% acha flour; 15% malted soybean flour) was notable for its Glutamic acid and Glycine content, suggesting enhanced nutritional properties (Ezegbe *et al.,* 2023). Sample E (75% acha flour; 25% malted soybean flour) was high in Glutamic acid, Glycine, and Aspartic acid, further indicating its nutritional richness.

The sample F (95% acha flour; 5% unmalted soybean flour) showed elevated levels of Aspartic acid, Glutamic acid, Methionine, and Valine, which could be particularly beneficial for dietary supplementation. Moreso, samples G (85% acha flour; 15% unmalted soybean flour) and H (75% acha flour; 25% unmalted soybean flour) had the least overall concentrations, but Sample G was notable for its Aspartic acid content (Ayo *et al.,* 2023).

Furthermore, the samples with higher concentrations of essential amino acids, like A and F, may be more nutritionally beneficial, especially for dietary supplementation (Li and Wu, 2020). This profile can guide the selection of samples for specific dietary needs or functional uses, such as sports nutrition requiring high Branched Chain Amino Acids (BCAAs) Leucine, Isoleucine, and Valine or other health-related dietary applications. This is consistent with WHO guidelines (WHO, 2022), which emphasize the importance of amino acid balance in achieving optimal nutrition.

Conclusion

The study was carried out on effects of malted soybean flour addition on the chemical composition, functional, physical and sensory properties of acha-based flour buscuit. The analysis of the Acha-based flour biscuits blended with malted and un-malted soybean flour reveals that malted soybean flour generally enhanced the chemical composition of the biscuits.

In terms of nutritional composition, sample E (75% Acha Flour and 25% Malted Soybean Flour) emerged with the highest protein, fat, and mineral content, particularly in potassium and magnesium. This sample also offered superior levels of vitamins, flavonoids, phenols, and carotenoids, contributing to its overall nutritional superiority. The acha-malted soybean flour blends, particularly at the 25% malted soybean flour inclusion, showed better results compared to the acha-un-malted soybean flour blends, which had lower nutrient and antioxidant levels.

Regarding anti-nutritional factors, acha-malted soybean flour blend biscuit Sample C (95% Acha Flour; 5% Malted Soybean Flour) showed reduced levels of oxalates, phytates, and trypsin inhibitors, enhancing digestibility. In terms of digestibility and antioxidant activity, Sample H (75% Acha Flour and 25% Un-Malted Soybean Flour) exhibited the highest antioxidant activity, while Sample E (75% Acha Flour and 25% Malted Soybean Flour) demonstrated the best protein digestibility.

Finally, the sensory evaluation indicated that the wheat flour-based Sample A was the preferred choice overall, although Sample F (95% Acha Flour and 5% Un-Malted Soybean Flour) performed best among the un-malted soybean flour blends. However, for optimal functional and nutritional properties, sample E (75% Acha Flour and 25% Malted Soybean Flour) emerged as the most superior blend, particularly in terms of nutritional content, and phytochemical properties.

Use of Malted Soybean Flour for Nutritional Enhancement: Malted soybean flour, especially at a 25% inclusion level (Sample E), could be recommended for fortifying Acha-based biscuits due to its superior nutrient composition, higher protein and fat content, and enhanced mineral and vitamin composition. This can improve the overall nutritional profile of the biscuits, making them more suitable for consumers seeking healthier snack options.

Acha-malted soybean flour blends, especially those with 5-15% inclusion levels, were found to have lower levels of anti-nutritional factors (such as oxalates, phytates, and trypsin inhibitors), making them a better option for enhancing the nutritional value of biscuits while reducing potential negative impacts on digestibility. This makes malted soybean flour an ideal ingredient for improving the health benefits of biscuits.

It was observed that incorporating malted soybean flour in Acha-based biscuits may enhances antioxidant activity, especially in terms of flavonoid and phenol content, which would be beneficial for consumers seeking products with antioxidant properties. Moreover, malted soybean flour could improve the protein digestibility, making it a better choice for individuals seeking products that support protein absorption.

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