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Incorporation of Chia Seeds into Scones: Effects on Nutritional Composition, Fatty Acids, and Sensory traits

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Abstract
The research problem lies in the need to improve the nutritional value of traditional baked goods without compromising their sensory characteristics, especially given the increasing trend towards using functional ingredients such as chia seed powder. In line with global directions toward sustainable foods, this study sought to identify the appropriate and feasible levels for incorporating chia powder into scones**.**An experimental study was conducted involving the preparation of scones in three treatments: a control sample, a sample fortified with 5% chia powder, and a third sample with 10% chia powder as a partial flour replacement. The samples were analytically evaluated in terms of nutritional content and fatty acid composition, in addition to a comprehensive sensory evaluation to determine the effect of fortification on product acceptability**.** The results showed that fortifying the scones with 5% chia powder led to a significant improvement in nutritional value, particularly in fiber, protein, and unsaturated fatty acid (omega-3) content, without causing significant changes in sensory characteristics. In contrast, 10% fortification contributed to a greater increase in nutritional value, especially in fatty acid and mineral content, but it was associated with slight changes in color and texture, which remained within acceptable sensory limits**.** These findings indicate that using chia powder at a rate of 5-10% achieves a functional and practical balance between enhancing the nutritional value of scones and maintaining their sensory characteristics at acceptable levels, while supporting the concept of sustainable foods through the incorporation of nutrient-rich, functional ingredients.

Keywords: Chia, Scones, Fatty Acid, Minerals, Fiber

Introduction
Developing new food products is a strategic area in the food industry, as consumers seek foods that combine traditional nutritional value with the added health benefits associated with regular consumption. With changing lifestyles, the demand for functional foods that support health is increasing, especially in the face of chronic diseases such as cardiovascular disease, hypertension, obesity, and diabetes, which are often linked to busy lifestyles and diets high in saturated fat. Incorporating total dietary fiber (TDF) into the daily diet is essential for improving overall health, as it contributes to lowering cholesterol, regulating blood sugar and insulin levels, improving bowel function, and enhancing antioxidant activity
In recent years, chia seeds (Salvia hispanica L.) have gained significant importance as a rich source of protein, fiber, and omega-3 unsaturated fatty acids, in addition to their high antioxidant properties and gluten-free nature. Chia seeds contribute to reducing food cravings, balancing blood sugar levels, improving cardiovascular health, lowering cholesterol, triglycerides, and blood pressure, and promoting weight loss. These seeds contain all the essential amino acids, including lysine, leucine, isoleucine, and valine, as well as branched-chain polysaccharide dietary fiber, which helps slow sugar absorption and improve digestion. Chia seeds are therefore an ideal ingredient for enriching food products with health benefits and enhancing the nutritional value of meals. Chia seeds (Salvia hispanica L.), native to Mexico and belonging to the Lamiaceae family, are a traditional seed that has been used throughout history in various forms, such as chia oil, porridge, and flour, in addition to being consumed whole (Din *et al*. 2021) [2]. These seeds are highly nutritious, containing significant amounts of dietary fiber (18-30%), β-3 and β-6 fatty acids, protein (approximately 23%), carbohydrates (approximately 41%), fats

(30%), and ash (4%) Chia seeds have garnered increasing attention in recent years due to their health benefits, including lowering blood pressure and possessing antioxidant activity, making them a popular choice among consumers who prefer health-enhancing foods (Orona *et al*. 2024), (Cotabarren *et al*. 2019) [3, 5]. This consumer trend has contributed to the growth of the functional food market, where chia is used as a nutritional value enhancer in various fortified food products. Several studies have explored the use of seeds as partial flour substitutes in baked goods, increasing dietary fiber and bioactive compound content while reducing calorie intake**.** Baked goods are a popular food among a large segment of the population (Moretton *et al*., 2023) [6]. They are consumed as breakfast snacks and as a main course with other meals.

They are made from flour, butter, margarine or oil, eggs, sugar, milk, and other ingredients. They are generally high in calories, due to their fat and carbohydrate content. Scones, or English rolls, are known for their flavor and soft texture. They are very tasty and widely accepted by consumers, despite their high calorie content. In this type of product, seeds can be used to replace some other ingredients and provide nutrients and bioactive compounds. The addition of seeds alters the color of baked goods in different ways, with specific volume decreasing and sensory properties increasing or decreasing depending on the concentration of added seeds (Martins *et al*., 2017) [7].

Materials and Methods

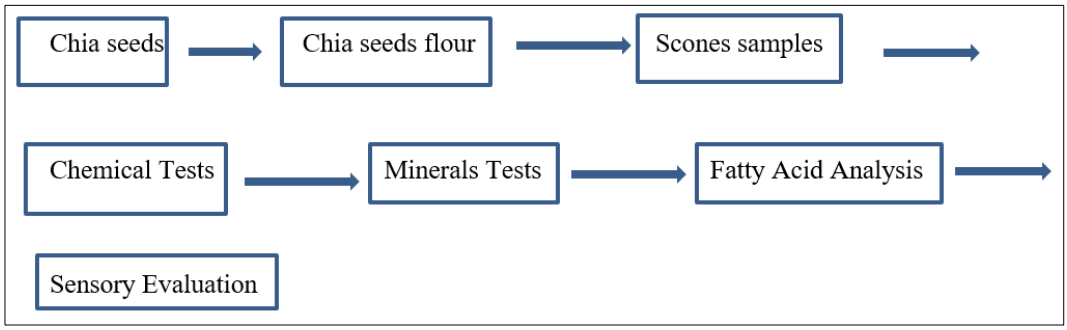

Fig 1: Reseearch Steps

Chia seeds were purchased from markets in Salah Al-Din, Iraq. The seeds were ground in a Philips mill before passing through a 210-micron sieve. All-purpose flour and baking ingredients (flour, eggs, sugar, baking powder, salt, milk, and margarine) were purchased from reputable commercial sources.

Scones Preparation

method of Scones preparation according to the method described by Quitral *et al*. (2025) [8]. The flour, ground chia seeds, sugar, salt, and baking powder were mixed together. Cold butter was added and rubbed in by hand until the mixture resembled coarse sand. The eggs and milk were gradually incorporated with a light kneading motion. The dough was divided into 50g rounds, approximately 3cm thick. The scones were baked at 200°C for 12-15 minutes, or until lightly browned. They were then cooled for 2 hours at room temperature, placed in polypropylene bags, and stored at 4°C for further analysis. A control sample and samples were prepared in which 5% and 10% of the refined wheat flour was replaced with chia seed flour. The scones replaced with chia flour were coded M0- control sample, M1-5% and M2-10%.The quantities are listed in Table 1.

Table 1: Scone formulations

Ingredients/formulations	M0	M1	M2
Flour (g)	52	52	52
Eggs (g)	6	6	6
Sugar (g)	3	3	3
Baking powder (g)	2	2	2
Salt (g)	1	1	1
Milk (mL)	25	25	25
Margarine (g)	11	11	11
chia seeds powder (g)	0	5	10

Chemical Tests

Scons samples were ground manually using a mortar and pestle, and the powders were passed through a 210-µm diameter sieve. Approximate structural analyses (wb) were performed on a wet basis, i.e., the crude protein content of the seed flour and scones samples, using standard protocols (AACC, 2012), and were expressed as a percentage.

Fiber Content

Chia seed powder and scones samples were analyzed to determine their total dietary fiber content according to the AOAC (2012) method, using the Total Dietary Fiber Test Kit provided by (Sigma-Aldrich, USA) 19. The results are expressed as a percentage of the dry weight of the sample.

Minerals

The mineral content, including iron (Fe), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), and zinc (Zn), was determined using atomic absorption spectroscopy (AAS, iCE 3000, Thermofisher, USA). Samples were digested with nitric acid in a 600W microwave-assisted digestion system for 15 minutes. Phosphorus was estimated using optical spectroscopy. Standard solutions and analytical curves were used for each element, and results are expressed in milligrams of the metal per 100 grams of sample (Goyat *et al*. 2018) [10].

Fatty Acid Composition

The lipids were extracted from the powdered samples using petroleum ether (boiling point = 60°C) with a Soxhlet apparatus. The extracted lipids were then saponified and esterified using methanolic solutions of KOH and HCl, respectively. The fatty acid methyl esters were then separated using gas chromatography (7890A, Agilent Technologies, USA), equipped with a fused silica capillary

column (HP-88, 100 m × 2.25 mm × 2.0 µm) and a flame ionization (FID) detector. The injector temperature was set at 20°C and the detector temperature at 250°C. To determine the fatty acids, the retention times of the samples were compared with those of standard fatty acid methyl esters. The composition of each fatty acid in the lipid sample was expressed as the peak relative density ratio in the chromatogram. (Goyat *et al*. 2018) [10].

Sensory Evaluation: The sensory acceptability of scones samples was assessed by a panel of thirty members. Quality attributes, namely color, texture, appearance, flavor, and overall acceptability (OAA), were evaluated. The assessment procedure was explained to the panel members. A nine-point sensory acceptability scale, based on "strongly dislike" and "strongly like," was used. The test was conducted mid-morning. Scones were randomly presented to the panel members, who were given ample time to evaluate them to avoid any misinterpretation. Water was provided for rinsing the mouth after each scone was assessed. The best scones samples were selected based on their sensory acceptability**.**

Statistical Analysis: The Statistical Packages of Social Sciences -SPSS (2019) program was used to detect the effect of difference groups/ factors in study parameters. Least significant difference-LSD was used to significant compare between means in this study.

Results and Discussion

Chemical analysis: Table 2 shows the results of the chemical analysis of chia seeds and scones. The significance level ($P \leq 0.01$) indicates highly significant differences among the treatments, confirming that the observed increases are statistically meaningful. The results showed that fortifying scones with chia seed powder resulted in a significant increase in protein content. The control sample (M0) was low in these key components (5.11 %). With the addition of 5% chia powder (M1), the protein content increased to 9.7 %, while fortification at 10% (M2) increased it to 10.6 %. This improvement reflects the rich nutritional properties of chia seeds, which contain 20% protein. The added protein enhances the nutritional value of scones and improves its amino acid profilile. The crude fiber content showed a significant increase, rising from 1.21% in the control sample (M0) to 4.5% in sample M1 and 5.16% in sample M2 at a 10% replacement level. This improvement is attributed to the high fiber content of chia seeds, which contain approximately 28% dietary fiber. The addition of chia seeds boosted the overall fiber content of the product, supporting improved nutritional balance and contributing to increased dietary fiber intake. Dietary fiber is known to promote digestive health, improve digestion, regulate blood sugar levels, and increase satiety. These findings align with the growing consumer trend toward functional baked goods that support metabolic health (Abreu *et al*., 2021; Slavin, 2013) [12, 13].

The increase in protein and fiber was directly proportional to the fortification percentage, confirming the effectiveness of chia seeds as a functional ingredient in improving baked goods. These results support the inclusion of chia seeds in baked goods as a scientifically sound strategy to enhance the nutritional value of products and provide tangible health benefits for consumers seeking protein- and fiber-rich foods**.**Fortifying baked goods with chia seeds represents a practical application of functional foods and offers a scientifically proven solution for improving baked goods quality, making them healthier and more nutritious. These results are consistent with studies indicating that chia seeds are rich sources of dietary fiber and protein (Da Silva Marinelli *et al*., 2014; Hussein *et al*., 2024a, 2024b; Katunzi-Kilwella *et al*., 2021; Motyka *et al*., 2023) [14, 15, 17, 18].

Table 2: Chemical analysis of chia seed powder and scones samples

Parameters	Chia seeds powder	M0	M1	M2	L.S.D.	P-value
Protein	20.0 ±1.03 a	5.11 ±0.26 c	9.7 ±0.72 bc	10.6 ±0.67 b	4.961 **	0.0001
Fiber	28.0 ±1.75 a	1.21 ±0.07 b	4.5 ±0.32 b	5.16 ±0.37 b	4.174 **	0.0001

Means having with the different letters in same row differed significantly.
** (P≤0.01).M0: Control sample, M1: Scones fortified with 5% chia seeds powder, M2: Scones fortified with 10% chia seeds powder.
**Highly Significant (P≤0.01).

Mineral Elements: Table 3 shows the results of the mineral analysis of chia and scones seeds. The minerals included phosphorus, calcium, potassium, magnesium, and iron. The mineral values in ground chia seeds were (780, 610, 432, 330, and 7.78 ppm), respectively. Mineral content analysis showed that fortifying scones with chia seed powder resulted in a significant and gradual increase in the concentrations of phosphorus, calcium, potassium, magnesium, and iron compared to the control sample M0, which had a value of (180, 63.5, 45.9, 12.40, and 1.50 ppm). The significance level ($P \leq 0.01$) indicates highly significant differences among the treatments. The mineral levels in sample M1 were (238, 80.5, 192, 41.2, and 2.28 ppm) and in sample M2, they were (257, 102, 213, 58.5, and 2.78 ppm). The values increased proportionally with the percentage of chia seeds added in both samples M1 and M2, reflecting the natural richness of chia seeds in these elements and demonstrating the effectiveness of the fortification process in enhancing the nutritional value of the product These results indicate that incorporating chia seeds at a rate of 5-10% significantly improves the mineral properties of scones, making them an effective ingredient in the development of healthy baked goods. The significant increase in mineral values is also attributed to the composition of chia seeds, which are a rich plant source of essential nutrients, and the stability of these minerals during mixing and baking, allowing for their efficient transfer to the final product with minimal loss. It is noteworthy that the increase was more pronounced in the minerals phosphorus, calcium, and magnesium due to their high original concentration in chia powder, while the increase in iron was relatively smaller due to its moderate level in the seed components. Overall, these results confirm that incorporating chia powder into baked goods recipes is an effective approach to enhancing nutritional value and improving product quality, and demonstrate the success of fortification strategies that

improve the mineral properties of scones in a technologically and nutritionally acceptable manner. This study is consistent with (Bochicchio *et al*., 2015; Hussein *et al*., 2024a, 2024b; Levent, 2017; Otondi *et al*., 2020;Ullah *et al*., 2016) [19, 16, 20, 21, 22].

Table 3: Mineral content of chia seed powder and scones samples

Parameters	Chia seeds powder	M0	M1	M2	L.S.D.	P-value
Phosphorus (P)	780 ±26.7 a	180 ±7.9 c	238 ±13.5 b	257 ±15.9 b	35.61 **	0.0001
Calcium (Ca)	610 ±22.9 a	63.5 ±3.6 c	80.5 ±4.3 bc	102 ±6.2 b	28.55 **	0.0001
Potassium (K)	432 ±19.3 a	45.9 ±2.9 c	192 ±11.8 b	213 ±11.6 b	31.04 **	0.0001
Magnesium (Mg)	330 ±16.4 a	12.40 ±0.72 d	41.2 ±2.6 c	58.5 ±2.4 b	15.91 **	0.0001
Iron (Fe)	7.78 ±0.56 a	1.50 ±0.08 b	2.28 ±0.31 b	2.78 ±0.27 b	1.382 **	0.0001

Means having with the different letters in same row differed significantly.
** (P≤0.01). M0: Control sample, M1: Scones fortified with 5% chia seeds powder, M2: Scones fortified with 10% chia seeds powder.
**Highly Significant (P≤0.01).

Fatty Acid Analysis: Table 4 shows the results of the fatty acid analysis of chia seeds and scones. Chia seed powder is rich in polyunsaturated fatty acids (PUFAs). Its main components are alpha-linolenic acid, linoleic acid, and oleic acid, at 20, 18, and 54 g/100 g, respectively. This is consistent with the known composition of chia oil, where alpha-linolenic acid ranges from 50 to 57 g/100 g, and linoleic acid from 17 to 26 g/100 g (Amato *et al*., 2015; Bocchichio *et al*., 2015; Oteri *et al*., 2022; Temelcina *et al*., 2017) [23, 24].

This demonstrates that fortifying scones with chia seed powder resulted in a clear and consistent increase in essential fatty acid content compared to the control sample. The significance level ($P \leq 0.01$) indicates highly significant differences among the treatments. This increase was directly reflected in the fortified samples. The ω-3 content increased from 1.0 g/100 g in the reference sample to 2.76 and 5.48 g/100 g in samples M1 and M2, respectively. A similar trend was observed for linoleic acid (ω-6), with its value increasing from 0.8 g/100 g in the control sample to 1.84 and 2.78 g/100 g in the two fortified samples. Oleic acid (ω-9) also increased from 0.4 g/100 g in the control sample to 0.60 and 1.70 g/100 g. These increased amounts indicate that the addition of chia powder at different concentrations enhanced the polyunsaturated fatty acid content of the scones, confirming the effectiveness of chia as a functional ingredient capable of improving the nutritional value of baked goods in a manner directly dependent on the percentage of addition. A study by Coelho and Salas-Mellado (Coelho *et al*., 2015) [4] indicated a growing demand for bread enriched with chia flour or chia seeds. The researchers demonstrated that adding 7.8 g/100 g of chia flour and 11.0 g/100 g of chia seeds to bread resulted in a final product with a better ratio of polyunsaturated fatty acids (PUFAs) to saturated fatty acids (SATs) compared to the control group. In conventional bread, the PUFA to SAT ratio was 1.01, while in bread enriched with chia flour or chia seeds, it was 3.1 and 3.9, respectively (Coelho *et al*. 2015) [4]. Overall, chia seed powder has demonstrated superior nutritional properties compared to wheat flour. Its high concentrations of protein, dietary fiber, essential minerals, and omega-3 fatty acids make it a promising ingredient for functional foods with potential health benefits.

Table 4: Fatty acid content in ground chia seeds and scones samples (g/100g)

Parameters	Chia seeds powder	M0	M1	M2	L.S.D.	P-value
Linolenic acid ω-3	54.6 ±2.37 a	1.0 ±0.02 c	2.76 ±0.15 bc	5.48 ±0.26 b	2.871 **	0.0001
Linoleic acid ω-6	20.18 ±1.08 a	0.8 ±0.13 c	1.84 ±0.06 bc	2.78 ±0.11 b	1.792 **	0.001
Oleic acid ω-9	7.15 ±0.37 a	0.4 ±0.08 c	0.60 ±0.08 bc	1.70 ±0.06 b	1.256 **	0.0001

Means having with the different letters in same row differed significantly.
** (P≤0.01).M0: Control sample, M1: Scones fortified with 5% chia seeds powder, M2: Scones fortified with 10% chia seeds powder.
**Highly Significant (P≤0.01).

Sensory Evaluation of Scones

Table5 presents the results of the sensory analysis of the scones samples. Sensory evaluation is a crucial stage in food product development, as achieving product acceptance at any industrial or local level is difficult without assessing consumer acceptability. The table presents the key sensory evaluation characteristics color, texture, appearance, flavor, and overall acceptability in the fortified samples.

The evaluation results showed that fortifying the scones with chia seed powder affected the studied sensory attributes to varying but similar degrees. The significance level ($P \leq 0.01$) indicates highly significant differences among the treatments. The control sample (M0) scored highest in all attributes, while the values gradually decreased with increasing fortification levels in M1 and M2.

Despite this, the 5% fortified sample (M1) maintained very close scores with the control sample in terms of color, texture, appearance, and flavor, while the 10% fortification of the scones (M2) resulted in a slight decrease in the acceptance of these qualities, attributed to the effect of chia powder on the color and texture of the dough

Regarding color, the control sample (M0) showed higher values than both M1 and M2. The addition of chia powder resulted in a darker color and less brightness, a pattern common in seed-fortified baked goods. This decrease is related to physical and chemical changes occurring during the baking process, and these observations are consistent with those of Yalcin *et al*. (2023) [27], who noted that chia-fortified biscuits have a darker color compared to wheat flour biscuits.

The texture, in terms of crunchiness, gradually decreased with increasing chia content. The control sample scored (10), while samples M1 and M2 scored (9.5, 8.3). The data show that sensory attributes related to texture are more

affected by chia addition than flavor and taste, which remain relatively stabl Consequently, moderate fortification levels, specifically up to 10%, may be more acceptable to consumers without compromising sensory integrity. These findings are consistent with previous studies by Goswami and Awasthi (2022) [28]. Fortifying biscuits with chia seed powder affects visual and texture characteristics more than flavor or taste. While sensory scores for color, appearance, and crunch decrease with increasing chia content, acceptance remains acceptable, especially at substitution levels between 5% and 10%. These results support the use of chia seed powder as a functional ingredient in baked goods, enhancing nutritional quality while preserving key sensory attributes (Azzam, 2025) [29]. As for flavor, the effect of chia powder becomes more pronounced at higher addition levels. This is supported by the study of Azzam *et al*. (2025) [29], which demonstrated that the flavor and taste of biscuits remained acceptable at low substitution levels (5-10%), with a decrease in overall acceptance at 15%. However, the current results show that overall acceptance remained high even at 10%, suggesting the possibility of incorporating chia into baked goods without a significant impact on sensory qualities. Similarly, Hussein *et al*. (2024) [29] did not observe significant differences in overall acceptance of chia-substituted biscuits up to 7%. Other studies (Sayed Ahmed *et al*., 2018) [30] also confirm that adding chia seeds can enhance nutritional value while maintaining acceptable sensory characteristics.

Table 5: Results of sensory evaluation of the scones samples.

Samples	Color	Texture	Appearance	Flavor	Overall acceptability
M0	10 ±0.00 a	10 ±0.00 a	10 ±0.00 a	10 ±0.00 a	10 ±0.00
M1	9 ±0.46 ab	9.5 ±0.59 a	9 ±0.46 ab	9.2 ±0.41 ab	10 ±0.00
M2	8 ±0.32 b	8.3 ±0.38 b	8.2 ±0.34 b	9 ±0.46 b	9 ±0.46
L.S.D.	1.203 *	1.096 *	1.44 *	0.972 *	1.06 NS
P-value	0.0438	0.0482	0.0377	0.0498	0.081

Means having with the different letters in same column differed significantly.
* (P≤0.05).* Significant (P≤0.05), Not Significant (NS)

Conclusion

Chia seed flour has been successfully incorporated into scones by partially replacing wheat flour. Replacing 5% with chia flour and 10% with chia seed flour resulted in high sensory acceptance and high nutritional value. The substitution led to a significant increase in protein, dietary fiber, polyunsaturated fatty acids, and minerals. The increase was evident. Chia seed flour can be used appropriately to develop baked goods with enhanced nutritional properties and high nutritional value.

Furthermore, adding chia seeds to baked goods at specific levels improves fatty acid levels and certain sensory properties, and reduces acrylamide levels in wheat bread formed during baking by increasing moisture content and decreasing starch content, as chia seeds are rich in fiber.

In recent years, there has been an increased interest in chia seeds. This material became the subject of many studies. Perspectives for the use of chia seeds relate to aspects health and also technological Chia can be part of the new foodstuffs with health-promoting qualities. The seeds are a good source of fibre and can be recommended for diabetes and people with hyper cholesterolaemia. Moreover they can be as supplement in the daily diet because of the high content of omega-3. Studies *in vitro* and *in vivo* confirm the health benefits of chia seeds. There are numerous proposals on the use of chia in dishes. Chia are characteristic because of the possibility of attractive looking gels and the seeds are used in the form of seed flour or whole seeds. Currently, chia seeds are used in Europe as a component of cereal products, e.g., breakfast cereals, rice crisps, wafers, chips. The use of chia seeds in production of dairy products, fruit and vegetables or meat stuffs have great perspectives.

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