Production of functional biscuits fortified with sweet almond flour and chia seeds

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Abstract
This study aimed to develop functional biscuits fortified with sweet almond flour and chia seed flour to enhance their nutritional and health-promoting properties. Biscuits were evaluated for proximate composition, mineral profile, total phenolic content (TPC), and sensory characteristics. The results showed that fortification with 50% almond or chia flour significantly improved the nutritional value compared with the control (wheat-based) biscuits. Protein, fat, ash, and mineral contents (Ca, Mg, Na, K, Fe) were markedly higher in fortified samples, while carbohydrate levels decreased (59.12% in almond and 57.98% in chia vs. 83.42% in control). Chia biscuits exhibited the highest mineral content, including calcium (11.01 mg/100 g) and potassium (49.04 mg/100 g). TPC values increased substantially, reaching 200 mg GAE/100 g in chia biscuits and 125 mg GAE/100 g in almond biscuits, compared with 45 mg GAE/100 g in the control. Sensory evaluation revealed that, although the control scored slightly higher for color and shape, fortified biscuits maintained high consumer acceptance (≈9.0 on the hedonic scale). Overall, fortification with almond and chia flours enhanced the nutritional and functional quality of biscuits without compromising sensory properties, supporting their potential as health-promoting functional foods.
Keywords: Functional biscuits, chia seeds, almonds, proximate composition, minerals, phenolic compounds, sensory evaluation.

1. Introduction

Biscuits are a snack and ready to eat among people and are available in different shapes and types around the world. It is one of the food products that Is prepared from basic ingredients such as wheat flour, fat, [1] and sugar. It has a texture that is somewhat spongy and with a certain degree of cohesion and fragility. Baking yeast is not used in its preparation, but rather baking seed powder, which produces the necessary gas to give the desired texture to the biscuits. There are currently more than 4,000 biscuits[2]. A type of biscuit, as It is available in many cities around the world, and no city is without factories to produce it Biscuits are one of the baking products commonly consumed all over the world by different segments of society due to their nutritional quality and readiness to eat. They are available in different flavors and have a relatively long shelf life, as they gain the approval of consumers all over the world, and due to their high consumption, it is possible to use them. As a food rich in dietary fiber , demand for which is increasing by the consumer, and many consumers have changed their nutritional habits, which has led to an increase in the marketing of foodstuffs that contain fiber by 10% annually, after increasing health awareness. The consumer considers the role of dietary fiber on health and nutrition and its contribution to solving widespread problems and diseases such as diabetes, obesity, gastrointestinal cancer, and high cholesterol levels. Dietary fiber, which is the edible part of plants or carbohydrates that resist digestion and absorption in the small intestine [2]. Researchers use natural sources to fortify and replace foods, due to their content of food components such as vitamins, proteins, mineral elements, and fats, and to also reduce the potential risks to human health from unnatural food additives This is consistent with what was mentioned by [3] .

This study aims to develop functionally enhanced biscuits fortified with natural dietary fiber sources to elevate their nutritional profile while maintaining desirable techno-functional and sensory attributes. It further seeks to respond to the rising global demand for high-fiber foods by evaluating natural fortification alternatives that can improve health-related benefits and reduce dependence on synthetic additives in bakery products.

2. Material and Methods:

Compound in biscuit manufacturing Kiin-Kabari and Giami Lupine, barley and oats are grains with nutritional and health value that have nutritional and pharmaceutical potential, meaning they have a positive effect on health and prevention (treatment of diseases), as the dietary fibers contained in these grains are considered healthy and functional foods and components. The basics. This is consistent with what was mentioned by [4]

2.1.Ground sweet almond:

Almond biscuits are a type of biscuit made from almonds. They are a common cookie in many different cuisines, and take many forms.

The chemical composition or Its components are an egg, sweet almond flour 50 grams, wheat flour 50 grams, fat 50 grams, sugar 60 grams, and milk 40 grams[4].

2.2.Ground chia seeds:

Suitable for weight loss, controlling blood sugar and blood pressure, improving nerve health, bone health, heart health, cancer prevention, eliminating insomnia, increasing energy, skin and hair health, The chemical composition or components are an egg, chia seed flour 50g, wheat flour 50g, sugar 60g, milk 40g, and fat 50g[4].

2.3.Estimation of Chemical Composition:

2.3.1. Determination of moisture ratio:

The percentage of moisture is calculated according to the following equation: 100x (drying before the explanation with sample weight – drying after award with sample weight) / (sample weight) = moisture percent ratio%

According to the method [4].

2.3.2. Determination of protein ratio:

The percentage of protein was estimated according to the approved method using a Kjeldahl device to extract the percentage of nitrogen, and from it the percentage of protein was calculated according to the following equation. Protein percentage (%) = (Nitrogen percentage x 5.75).

]**4**According to the method [

2.3.3. Determination of fat ratio:

The percentage of fat was calculated according to the following equation bellow using a Soxhelet device and following the standard method . This was done by using the saxolyte device and hexane as an organic solvent. The process was carried out by taking 2 grams of the sample, placing It on filter paper, and recording Its weight. Then it was transferred to the device’s warehouse. The media was washed well and dried, and hexane was placed

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In it to 3/4 of the capacity. The parts of the device were formed and the extraction was performed.

The extraction continues for a period of 8-12 hours. After that, samples are taken with filter paper and dried at a temperature of 70°C, then the following weights are taken.

$$]5 \text{Weight of fat} = \frac{\text{fat weight}}{\text{(sample weight}} \times 100\ [$$

2.3.4. Determination of Ash ratio:

The following equation . (Empty ash weight – after cremation of the sample with the ash weight)/(Sample weight)=Percentage of ash 100X,These methods were applied according to the method described by [5].

2.3.5. Determination of carbohydrates ratio:

The method for estimating the percentage of carbohydrates is calculated from the difference between the ingredients subtracted from 100 percent .

Carbohydrates=100-(Moisture+Protein+Fat+Ash) %

According to the method [6]

2.3.6. Estimating mineral elements:

Mineral elements in biscuit samples were estimated using an atomic absorption device according to the method after dry incineration of the samples in the following way:

The weight of 2 grams of biscuit samples was taken and placed in a pre-dried ceramic jar and Its weight was fixed. Then It was dried using an electric oven at a temperature of 100 to get rid of moIsture. The jars were then transferred to an incineration oven at a temperature of 600 until the weight was stable and a white powder was obtained and to estimate the quality and proportions of the metals to be detected. They are Iron, zinc, copper, manganese, magnesium, calcium, sodium and potassium. 5 ml of 5% nitric acid was added to the obtained ash and mixed well, then filtered using filter paper. It was estimated using an atomic absorption device for each metal to be Identified and measured by placing the sample in the form of a transparent liquid. In the device and estimate its percentage directly This is consistent with what was mentioned by [5].

2.4.Total phenols in biscuits made from wheat flour, almonds, and chia seeds Method for determining phenolic compounds

Phenolic content was estimated according to the method mentioned in According to the method described by [9], where 2 ml of the sample was weighed in a volumetric flask with a capacity of 10 ml, and 3 ml of distilled water and 2.5 ml of Folin-Ciocalteu reagent were added to it. The flask was shaken for 4 minutes, then 2 ml of sodium carbonate solution, add the volume to the ratio and mix. Mix well and leave for two hours, then the absorbance Is read at a wavelength of 750 nm using a spectrophotometer.

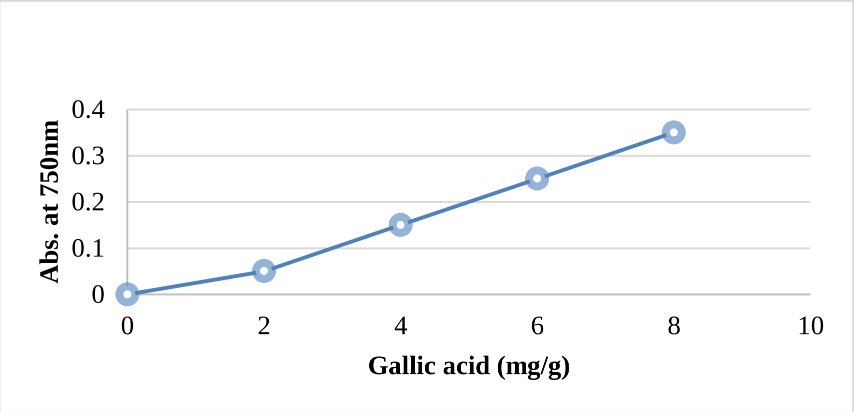

Figure (1) Standard Curve gallicid

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Table (1) Sensory Evaluation Form

Evaluation	The attribute						
	The shape	Texture	Taste	The smell	The color	Public acceptance	Feeling after chewing
1. I don't like it at all 2. I didn't like it very much 3. I didn't like it quite a bit 4. I didn't like it a bit 5. I neither reject it nor accept It 6. I liked It a little 7. I kinda liked it 8. I liked It very much 9. I liked It a lot							

Table (1) shows the sensory assessment form Sensory tests were conducted In the laboratories of the Food Sciences Department/College of Agriculture/Tikrit University, and the manufactured biscuit samples were evaluated sensory by (10 people) according to the sensory evaluation form shown in the table.

The extent of the consumer's general acceptance of the studied sensory characteristics (shape, texture, taste, smell, color, general acceptance, and sensation after chewing) by conducting the questionnaire according to the Nine-point Hedonic Scale method , whichh is based on giving samples and numbers from (9). -1), which ranges from 9 = I liked it very much to 1 = I did not like It at all. Appendix (2) shows an aspect of the sensory evaluation process. According to the method [5]

3. Results and discussion

3.1. Chemical composition of biscuit

Table (2) shows the chemical composition of biscuits made from wheat flour, sweet almond flour, and chia seeds

Component	Control flour biscuits	Sweet almond flour cookies	Chia seed cookies
Humidity %	5.60 ± 0.15 (c)	7.71 ± 0.12 (a)	6.29 ± 0.14 (b)
Protein %	8.91 ± 0.16 (c)	18.91 ± 0.14 (a)	16.22 ± 0.15 (b)
Fat %	1.06 ± 0.12 (c)	11.22 ± 0.18 (b)	15.41 ± 0.17 (a)
Ash %	1.04 ± 0.11 (c)	3.09 ± 0.14 (b)	4.11 ± 0.13 (a)
Carbohydrate %	83.42 ± 0.17 (a)	59.12 ± 0.16 (b)	57.98 ± 0.18 (c)

- Similar letters in the same row indicate no significant differences at $P > 0.05$

Table (2) presents the proximate composition of the biscuit samples. Significant differences were observed among the treatments as a result of replacing 50% of wheat flour with either almond or chia flour. Moisture content increased in the fortified samples, with almond biscuits recording the highest value (7.71%) compared with 6.29% in chia biscuits and 5.60% in the control. The increase in moisture in fortified samples can be attributed to the higher water-binding capacity of proteins and fibers present in almond and chia flours, which are known to retain more water during dough mixing and baking[7].

Protein content improved remarkably in fortified biscuits, reaching 18.91% in almond and 16.22% in chia, compared with only 8.91% in the control. This nearly two-fold increase clearly reflects the high protein density of almond and chia seeds and demonstrates the strong nutritional impact of the 50% substitution level. Such improvement is consistent with previous studies reporting protein enrichment in baked goods fortified with nut and seed flours [7];[2].

Fat content was also significantly elevated in the fortified samples, particularly in chia biscuits (15.41%), followed by almond biscuits (11.22%), compared with 1.06% in the control. This is expected given the lipid-rich composition of chia and almonds, which are known sources of polyunsaturated fatty acids such as linoleic and α-linolenic acids. The presence of these health-promoting lipids enhances the functional value of the fortified biscuits, aligning with consumer demand for products with cardiovascular benefits [6].

Ash content, an indicator of total mineral matter, was highest in chia biscuits (4.11%), followed by almond biscuits (3.09%), and lowest in the control (1.04%). This reflects the high mineral content of chia and almond seeds and suggests that their incorporation into biscuits markedly improves the micronutrient profile[7].

In contrast, carbohydrate content decreased significantly in the fortified samples (59.12% in almond and 57.98% in chia) compared with the control (83.42%). This reduction is explained by the replacement of wheat flour, rich in starch, with almond and chia flours that contain lower carbohydrate but higher protein, lipid, and fiber fractions. Such a decrease is nutritionally favorable, especially for consumers aiming to reduce glycemic load and manage weight.

Overall, the 50% substitution of wheat flour with almond or chia flour substantially enhanced the nutritional profile of biscuits, with improvements in protein, fat, and mineral content, alongside a reduction in carbohydrate levels. These changes confirm the functional potential of almond- and chia-fortified biscuits as healthier alternatives to conventional wheat-based products.

3.2. Composition of mineral elements in biscuit samples:

Table (3) presents the mineral composition of the biscuit samples. Substituting 50% of wheat flour with almond or chia flour resulted in significant increases in mineral content across all evaluated elements. Calcium content was highest in chia biscuits (11.01 mg/100 g), followed by almond biscuits (9.08 mg/100 g), compared with only 7.62 mg/100 g in the control. This reflects the high calcium density of chia and almond seeds, which are recognized as good dietary sources of this mineral.

Magnesium values ranged from 8.53 mg/100 g in the control to 13.19 mg/100 g in chia biscuits, while almond biscuits provided an intermediate value (10.28 mg/100 g). Such an increase is nutritionally relevant given the role of magnesium in enzymatic processes, protein synthesis, and energy metabolism.

Sodium content, although naturally present in the raw materials, also increased significantly in the fortified biscuits, with chia-based samples recording the highest value (33.06 mg/100 g). While sodium is essential in small amounts for fluid balance and nerve function, its elevated content should be considered in terms of dietary recommendations.

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Potassium content increased markedly from 35.27 mg/100 g in the control to 42.15 mg/100 g in almond biscuits and 49.04 mg/100 g in chia biscuits. The higher potassium-to-sodium ratio observed in fortified biscuits is of particular importance, as this balance contributes to the regulation of blood pressure and cardiovascular health.

Overall, the results demonstrate that replacing 50% of wheat flour with almond or chia flours substantially enriched the mineral profile of biscuits. Chia flour, in particular, provided the highest levels of calcium, magnesium, potassium, and iron, highlighting its

superior potential for improving the micronutrient density of baked products. These findings are consistent with previous studies reporting mineral

Iron content also showed significant improvement, with chia biscuits reaching 3.02 mg/100 g compared with 2.16 mg/100 g in almond biscuits and 1.89 mg/100 g in the control. This indicates that fortification with chia and almond flours can enhance the iron content of biscuits, contributing to the prevention of iron-deficiency anemia, particularly in populations relying on plant-based diets.

enrichment in baked goods fortified with seed and nut flours [6];[7].

Table 3: Mineral composition (mg/100 g) of biscuit samples

Component	Control (spelt flour biscuits)	Sweet almond biscuits	Chia seed biscuits
Calcium	7.62 ± 0.15 (c)	9.08 ± 0.16 (b)	11.01 ± 0.18 (a)
Magnesium	8.53 ± 0.14 (c)	10.28 ± 0.15 (b)	13.19 ± 0.17 (a)
Sodium	22.90 ± 0.19 (c)	27.13 ± 0.21 (b)	33.06 ± 0.22 (a)
Potassium	35.27 ± 0.20 (c)	42.15 ± 0.23 (b)	49.04 ± 0.25 (a)
Iron	1.89 ± 0.11 (c)	2.16 ± 0.12 (b)	3.02 ± 0.13 (a)

- Similar letters in the same row indicate no significant differences at P > 0.05

3.3. Estimated total phenolic content (TPC) of biscuit samples

Table 4. Estimated total phenolic content (TPC) of biscuit samples (mg GAE/100 g)

Sample	TPC (mg GAE/100 g)
Control (spelt flour biscuits)	45.0 ± 5.0 (c)
Sweet almond biscuits (50% replacement)	125.0 ± 10.0 (b)
Chia seed biscuits (50% replacement)	200.0 ± 15.0 (a)

- Similar letters in the same column indicate no significant differences at P > 0.05.

Table (4) presents the estimated total phenolic content (TPC) of biscuit samples. A clear and significant variation was observed among the treatments. Chia seed biscuits recorded the highest TPC value (~200 mg GAE/100 g), followed by almond biscuits (~125 mg GAE/100 g), while the control exhibited the lowest content (~45 mg GAE/100 g). The significantly higher TPC values in fortified biscuits can be attributed to the inherent richness of chia and almond flours in bioactive phenolic compounds such as caffeic acid, gallic acid, rosmarinic acid, and flavonoids (quercetin, kaempferol, and myricetin).

The incorporation of 50% chia flour led to the greatest enhancement, which is consistent with earlier studies reporting chia seeds as a superior source of phenolic compounds with strong antioxidant activity [7]. Similarly, almond flour also contributed considerably to the

phenolic profile, in line with findings that almonds contain diverse phenolic acids and flavonoids contributing to antioxidant capacity [6].

The observed reduction in TPC values compared with raw flour values may be explained by the degradation of thermolabile polyphenols during baking, as highlighted in studies on fortified bakery products [1];[2]. Nevertheless, even after baking, the fortified biscuits retained substantially higher phenolic contents than the control, confirming that fortification is effective in improving the functional quality of baked good[8].

Overall, the results demonstrate that fortifying biscuits with chia and almond flours significantly enhanced their phenolic content and potential antioxidant activity. This supports the classification of these products as functional foods, contributing to consumer health through natural bioactive compounds.

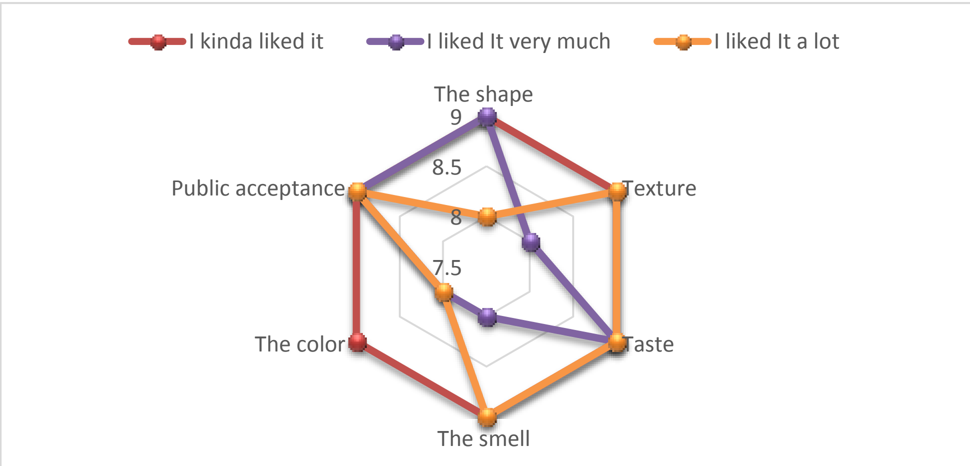

Figure 3 Sensory evaluation of biscuit samples made from wheat flour, sweet almond flour and chia seed flour.

Figure (3) illustrates the sensory evaluation of biscuits made from wheat flour (control) and those fortified with chia and almond flours. The results reveal that the control biscuits consistently scored highest across most sensory attributes, particularly in shape, color, and texture, with values approaching 9.0. This suggests that consumers are more accustomed to the

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sensory profile of traditional wheat-based biscuits[9].

Color, as an important determinant of consumer acceptance, was rated best in the control biscuits, confirming the visual preference for lighter-colored baked goods. Texture scores were highest in both control and almond-fortified biscuits, indicating that almond flour incorporation maintained a desirable crispness and structural quality.

Regarding smell and taste, almond biscuits achieved comparable scores to the control, while chia biscuits received slightly lower values. This reduction may be linked to the darker color and distinct nutty aroma of chia, which can influence consumer perception, as noted in earlier studies on seed-fortified bakery products [1]; [6].

Despite these variations in individual attributes, overall acceptance was rated equally high (≈9.0) across all treatments, highlighting that fortification with chia and almond flours did not compromise consumer acceptance. These findings are consistent with previous reports that functional enrichment of baked products can alter specific sensory traits (e.g., color, flavor) while maintaining high overall acceptability [2];[7].

In summary, while the control biscuits outperformed in certain traits such as color and shape, almond- and chia-fortified biscuits maintained acceptable sensory quality and comparable consumer approval. This supports the feasibility of developing fortified biscuits that combine functional benefits with consumer appeal.

Conclusions

The incorporation of 50% sweet almond and chia flours significantly improved the nutritional quality of biscuits, increasing protein, fat, ash, minerals, and phenolic content while reducing carbohydrates. Chia biscuits provided the highest mineral and antioxidant levels, whereas almond biscuits enhanced protein enrichment. Despite minor sensory differences, overall consumer acceptance remained high. These results support the development of almond- and chia-fortified biscuits as functional foods with improved nutrient density and strong consumer appeal.

Supplements

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