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Improving the Quality of Wheat Rusk using Chia Seeds (*Salvia hispanica* L.)

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Abstract

Chia seeds are rich in many vital compounds such as antioxidants, fiber, ash, protein, essential amino acids and polyunsaturated fatty acids (PUFA). These compounds have nutritional, biological and therapeutic value for many metabolic diseases, such as resistance to free radicals, obesity, diabetes, and reducing cardiovascular disorders. This study aimed to replace wheat flour with 0, 2, 4, and 6% of chia seed flour, or 0, 3, 6, and 9% of defatted chia seed flour, to prepare breadcrumbs with high nutritional value. The results showed that the content of chia seed flour of protein, ether extract, ash and crude fiber exceeds the content of wheat flour by 54.36, 91.63, 53.13 and 94.49%, respectively. Replacing wheat flour with 6% chia seeds or 9% defatted chia seeds resulted in an increase in most minerals, as well as essential amino acids increased to 26.61 and 172.65%, respectively. Increasing the replacement ratio resulted in a slight change in the rheological and sensory properties such as colour, flavour, texture and general acceptance. Therefore, we recommend replacing wheat flour with 9% defatted chia seeds or 6% chia seeds to prepare rusks or similar crackers to improve their quality and increase their nutritional value.

Keywords: Improving, quality, rusk, wheat flour, chia seeds.

1. Introduction

Chia seeds (*Salvia hispanica* L.) is a summer annual plant belonging to the Labiatae family [1]. Its compact, flattened, oval seeds range in size from 2 to 2.5 mm in length, 1.2 to 1.5 mm in width, and 0.8 to 1 mm in thickness. It comes in two shades, 2.5 and 2.6, ranging in colour from dark brown to black, occasionally grey, or even white; the white seeds are heavier, wider, and thicker than the darker ones [2]. Due to its many useful characteristics, chia has become a particularly popular novel food ingredient among researchers. *Salvia hispanica* L., sometimes known as chia, is an annual flowering plant in the mint family (family Lamoaceae) that stands out for its medicinal and nutritional qualities [3]. Linolenic and linoleic acids may make up much to 60 and 20%, respectively, of the overall composition of chia oil [4], with a ratio of about 1:3. Chia seeds typically yield 25–40%of oil following extraction [5]. According to reports, chia has high levels of protein, ash, dietary fiber, and oil, with respective ranges of 15–25%, 4-5%, 18–30%, and 30–33% respectively. Chia contains antioxidants and 26-41% carbs [2]. The importance of chia seeds as a functional food and nutritional supplement cannot be overstated [6]. Climate, provenance, and extraction techniques are a few of the variables that affect the make-up and concentration of their bioactive components [7] [8].

In our nation, rusk is a pretty old product. It is a bakery item made using Suji and flour, it is eaten as a snack with tea and milk and has a mildly sweet flavour. Its preparation is fairly straightforward It can be kept for a very long time, up to two or three months they spend very little on storage. Even the average person may readily buy this product from the bakery because it is so inexpensive, both urban and rural communities are big fans of them. Everyone enjoys rusk, a highly regarded baked food, especially children and working people in both rural and urban classrooms [9][10].

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Consumers today demand both taste and nutritional quality since they are becoming more and more concerned about their health. It is becoming increasingly clear that even if baked goods made from refined flour taste good, the toxic ingredients they contain produce a variety of negative health impacts in humans. So, it is thought that safe and nutritious substances should be used in place of refined flour. As a result, products made from composite flours are currently popular [11].

Due to their roles in modifying cell membrane fluidity and function, cell signaling, and the transcriptional regulation of gene expression, omega-3 polyunsaturated fatty acids (PUFA) are crucial for nutrition and health. They play a crucial role in lipid homeostasis. The link between PUFA deficiency and risk for disorders like metabolic syndrome, insulin resistance, cardiovascular, and neurological diseases has been shown in numerous research [12][13]. Studies have concentrated on their potential therapeutic application for various lipid-related illnesses, including both preventive and curative treatments as dietary supplements. Both marine organisms and plants contain omega-3 fatty acids. Interest has shifted to plant-based products as an intriguing alternative and potential source of PUFA because the former may be in short supply or pose a concern due to its allergenicity [14]. The important fatty acid linolenic acid (ALA), a precursor to Docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), is particularly abundant in seed oils (EPA). ALA itself exhibits anti-inflammatory and neuroprotective qualities, making it potentially useful as a tool for lowering the risk of diseases associated with it. Chia seeds contain up to 20% linoleic acid and about 65% ALA of their total oil, according to studies on their chemical make-up [12][14][15]. Chia seed oil also has antioxidants properties [12][14][15][16], which may help explain why people are interested in this product for its nutritional and health benefits. Chia seed oil has a high PUFA content (about 80%), which makes it vulnerable to oxidation and increases the risk of unwanted toxic product production as well as nutritional value loss during storage. The main determinant of the quality of edible vegetable oil is its oxidative stability [12][17]. Hence, enhancing chia seed oil's stability and protecting PUFA from degradation is crucial for its usage in nutrition and health applications, such as the creation of functional foods or pharmaceuticals. The production of affordable, wholesome, and practical food is a challenge for the food industry. Due to the bioactive components that are included in functional foods or added to traditional formulations, they have the ability to promote health.

This study aims to replace a percentage of the wheat flour used in the manufacture of rusks with chia seed flour or defatted chia seed flour, and to study the effect of this on its quality as well as its content of important nutritional elements necessary to enhance the health of its consumers.

2. Material and methods

2.1. Materials:

- Chia seeds (*Salvia hispanica* L.) were purchased from local market at Kafr El-Sheikh, city, Egypt.
- Wheat flour 72% extraction were purchased from delta middle and west Milling company, at Tanta city, Egypt.
- Other ingredients (yeast, sugar, corn oil, and salt) were purchased from local market at Kafr El-Sheikh, city, Egypt.
- Chemicals used were purchased from El-Gomhoria pharmaceutical company of Tanta city at El-Gharbia Governorate Egypt.

2.2. Methods:

2.2.1. Preparation of chia seed powder:

Seeds cleaned manually and strong matter, like stones, uncleanness and cracked seeds were removed. Thereafter, dried in an oven at 50°c for 16 h. an electric stainless-steel grinder (Panasonic) was used to grind chia seeds to fine powder (60-80 mesh) to get chia powder, then stored until analysis.

2.2.2. Preparation of defatted chia seeds

The oil was obtained from the chia seeds in a hydraulic press (MECAMAQ Model DEVF 80, Vila-Sana, Lleida, Spain) as described by [18]. The defatted chia seed meal was grounded at 10,000 rpm for 3 min with a knife mill GRINDOMIX GM 200 (Retsch, Haan, Germany) and stored vacuum-packed in darkness at 4 °C until use.

2.2.3. Rusk dough preparation

Rusk dough had been prepared according to the standard method of [19] as follows:

Wheat flour 72% extraction was used with different substituting percentages of chia seeds, (2, 4, and 6%,) and defatted chia seed powder with substituting percentages 3, 6, and 9%, to prepare rusk, in addition to the rest of the ingredients indicated in the Table (A). By using a mixer ingredients mixing was done for dough preparation. Then dough was molded, panned, and proofing was done at 30 °C and 85% RH for 45 min for optimum dough development. Then baked for 15-20 min at 225 °C. After that the cooling of the bread was done, again proofed sliced and final baking (150 °C/15 min) was done to obtain the crispy rusk.

Table A

Rusk preparation using chia seeds and defatted chia seed powder

Ingredients	Control	Chia seeds			Defatted chia seed		
		2%	4%	6%	3%	6%	9%
Wheat Flour (g)	500	490	480	470	480	470	455
Sugar (g)	18	18	18	18	18	18	18
Oil (mL)	18	18	18	18	18	18	18
Salt (g)	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Yeast (g)	6	6	6	6	6	6	6
Water (mL)	170-180	170-180	170-180	170-180	170-180	170-180	170-180

Control= Wheat flour 72% extraction

2.2.4. Gross chemical composition

Moisture content, ether extract, protein, ash and crude fiber were determined according to [20], available carbohydrates were calculated by difference as follows:

Available carbohydrate (%) = 100 - (protein + ether extract + ash + fiber)

2.2.5. Determination of minerals contents

Minerals content of samples were performed using different equipment's. whereas the atomic absorption spectrophotometer (Zeiss FMD3) was used to determine magnesium, iron, zinc and copper. the flame photometer was used for the determination of sodium, potassium and calcium. Phosphorus content was determined calorimetrically. According to the methods of [20].

2.2.6. Determination of amino acids

Amino acids were determined in agricultural research center, Cairo, according to the method described by [21]. Tryptophan content of samples was determined calorimetrically, in the alkaline hydrolysate following the method of [22].

2.2.7. Farinograph method

The dough mixing measurements of different wheat-DCSF flour mixtures were examined with the Brabender farinograph (Brabender, Duisburg, Germany) according to the constant flour weight process [23][24]. Dough development time was determined as the time to the point of the curve immediately before the first sign of a decrease in consistency. The maximum consistency was defined as the consistency in B.U., measured at the development time and in the middle of the curve bend, while the dough stability was defined as the drop of the curve (B.U.) during the first 2 min after dough development time.

2.2.8. Extensograph method

Doughs from the farinograph properties were cut into two parts (150g each) and passed through the balling and molder unit of a Brabender extensograph (Brabender, Duisburg, Germany). After 45 min rest in the fermentation cabinet, the dough was stretched. After this first test, the balling and mounding operations were repeated and the doughs were tested again after a further 45 min resting time. The same procedure was repeated for a third time, following the official procedure [23][24]. The results were expressed as the resistance to constant deformation after 50 mm stretching (R50); the extensibility (Ex) was described as the distance traveled by the recorder paper from the moment that the hook touches the test piece until the rupture of the test piece and the ratio between them (R50/Ex).

2.2.9. Organoleptic properties of rusk

Sensory evaluation of rusk was estimated by 20 panelists from the food science and technology department faculty of agriculture, Kafr El-Sheikh University, Egypt, Panelists were asked for sensory properties of rusk color, taste, flavor, odor, texture, crunchy and overall acceptability according to the method outlined by [25]. Panelists estimated rusk blends on a 9-point hedonic scale quality analysis.

2.2.10. Statistical analysis

Data were subjected to statistical analysis using done SPSS program to find the variation. ANOVA was applied to analyses the data, and Duncan's.

3. Results and decussation

3.1. Chemical composition of formulas

Table (1) shows the chemical composition of formulas on a dry weight basis (g/100g). The results indicated that the moisture and carbohydrate content of wheat flour was higher than the content of chia seeds by 1.75 and 66.70%, respectively. multiple range test was used to determine differences that were statistically significant ($p \leq 0.05$).

While the content of chia seeds of protein, fat, ash, and crude fiber increased over the content of wheat flour by 12.83, 23.09, 2.04, and 32.07%, respectively. Accordingly, it was found that the greater the proportion of replacing a portion of wheat flour with a portion of chia seed or defatted chia seed flour during the manufacture of rusks, the greater the content of the rusk in terms of protein, fat, ash and crude fiber, at approximately the same rate as the substituting ratio.

Table 1 Chemical composition of formulas (dry weight)

Chemical composition (g/100g)	Chia seeds	Defatted chia seeds	Wheat flour	Control rusk	whole chia seeds rusk (%)			Defatted chia seed flour rusk (%)		
					2	4	6	3	6	9
Moisture	5.75[d]	3.61[f]	7.50[b]	12.17[a]	4.14[e]	6.13[c]	7.14[b]	2.13[g]	3.13[f]	5.14[d]
Protein	23.60[e]	33.74[a]	10.77[j]	11.49[i]	19.11[h]	20.34[g]	22.56[f]	25.21[d]	27.53[c]	29.85[b]
Fat	25.20[a]	2.00[f]	2.11[f]	6.50[e]	10.70[d]	13.80[c]	17.90[b]	6.68[e]	6.65[e]	6.61[e]
Ash	3.84[d]	7.79[a]	1.80[e]	0.82[f]	3.60[d]	4.68[c]	5.76[b]	1.62[e]	2.71[d]	3.82[d]
Crude Fiber	33.20[b]	36.4[a]	0.50[i]	0.95[i]	16.47[h]	18.29[g]	20.11[f]	27.64[e]	29.63[d]	31.62[c]
Carbohydrates	14.16[i]	20.07[h]	84.82[a]	80.24[b]	50.12[c]	42.89[d]	33.67[f]	38.85[e]	33.48[f]	28.10[g]

Different letters indicate to significant difference between formulas in the same column ($P < 0.05$).

Control rusk= Wheat flour 72% extractio

The results of the chemical composition of the formulas indicated that increasing the percentage of replacing a portion of wheat flour with a portion of chia seeds or defatted chia seed flour during the manufacture of rusks, led to an increase in its content of protein, fat, ash, and crude fiber, at approximately the same rate as the replacement percentage, and this is due to the content of the seeds. High shea is one of these compounds. These results were close to the results obtained by [26] where they showed that pan bread prepared with chia seed powder had higher protein, ash, crude fiber and fat content compared to pan bread made from wheat flour only. [27] studied the risk/benefit assessment of chia seeds as a new ingredient in grain-based foods and found that the results suggest that replacing part of the wheat grain with a part of chia seeds in new grain-based formulations would improve the nutritional profile of the products, but also increase Occurrence of contaminants in chemical processes, so this paradox should be carefully considered in the context of risk/benefit analysis.

3.2. Minerals content of rusk substituted with chia seeds or their defatted flour.

Table (2) shows the effect of replacing a percentage of wheat flour (control) with a percentage of chia seeds (2, 4, and 6%), or a percentage of their flour (3, 6, and 9%) on the mineral content of the rusks made from them. The results showed that the mineral content of chia seeds was higher than that of wheat flour by 67.87, 79.50, 78.85, 95.95, 71.43, 11.62 and 93.71% for Sodium, Potassium, Magnesium, Calcium, Iron, Copper and Phosphorus, respectively. It was also noted that the most quantitative mineral elements in chia seeds were phosphorous, followed by calcium, then potassium, then magnesium, which were 798.00, 701.38, 489.10 and 391.91b g/100 g on dry weight basis, respectively. The results in Table 2 also showed that wheat flour contained more zinc than chia seeds by 34.57%. Based on these results, it was observed that the rusk made from wheat flour, substituted with proportions of chia seeds or defatted flour, increased its content of mineral elements with an increase in the substituting ratio.

Increasing the proportion of replacing wheat flour with defatted and non-defatted chia seed flour in the mixtures for making rusk, led to an increase in its content of mineral elements compared to rusks made from wheat flour alone, and that the increase was greater in the mixtures that contained defatted chia flour. The reason for this is due to the high content of chia seeds of mineral elements compared to wheat grains and removing the fat from chia seeds led to an increase in the rest of the dry matter components in the seeds, and thus increased the mineral content of the rusks made from them compared to the rusks made from non-defatted chia seeds. These results are consistent with the work of [28] [29] which showed that the chemical composition of toast bread prepared from wheat flour contains some essential amino acids, which constitute such a mixture in this study.

Table 2 Minerals content of baked rusk prepared using chia seeds and their defatted flour (g/100 g on dry weight)

Minerals	Chia seeds	Defatted chia seeds	Wheat flour	Control rusk	Defatted flour chia rusk			Chia seeds rusk		
					3%	6%	9%	2%	4%	6%
Sodium	19.30^{b}	29.02^{a}	6.20^{c}	4.10^{e}	4.40^{e}	4.70^{e}	5.00^{d}	4.84^{e}	5.59^{d}	6.34c^{d}
Potassium	489.10^{b}	840.23^{a}	100.23^{i}	97.30^{j}	105.13^{h}	112.96^{g}	120.80^{e}	119.58^{f}	141.88^{d}	164.16^{c}
Magnesium	391.91^{b}	510.65^{a}	82.87^{g}	70.40^{i}	76.82^{h}	83.25^{f}	89.63^{e}	83.58^{f}	96.82^{d}	110.01^{c}
Calcium	701.38^{a}	680.93^{b}	28.36^{i}	25.70^{j}	43.75^{h}	52.72^{f}	66.22^{d}	45.32^{g}	65.03^{e}	84.66^{c}
Iron	10.93^{a}	9.91^{b}	3.12^{c}	1.53^{g}	1.71^{eg}	1.90^{f}	2.00^{def}	1.77^{eg}	2.03^{def}	2.28^{d}
Zinc	2.10^{c}	5.10^{a}	3.21^{b}	2.95^{c}	2.93^{b}	2.91^{b}	2.18^{c}	3.15^{b}	3.07^{b}	3.14^{b}
Copper	0.43^{b}	1.50^{a}	0.38^{cd}	0.34^{d}	0.33^{d}	0.34^{d}	0.34^{d}	0.37^{cd}	0.40bc	0.44^{b}
Phosphorus	798.00^{b}	980.47^{a}	50.13^{h}	44.00^{i}	59.08^{g}	74.16^{f}	89.24^{e}	72.08^{f}	100.18^{d}	128.27^{c}

Different letters indicate to significant difference between formulas in the same row ($P < 0.05$).

Wheat flour 72% extraction.

3.3. Amino acid composition of rusk substituted with chia seeds and their defatted flour.

The results in Table 3 show the content of chia seeds and their defatted flour, as well as wheat flour and rusks made from them. The results showed that the protein content of chia seeds and their defatted flour of essential and non-essential amino acids was higher than that the protein content of wheat flour, with the exception of glutamic acids and proline, of which the content of wheat flour was higher. Increasing the percentage of replacing wheat flour with a percentage of defatted and non-defatted chia seed flour led to an increase in the essential amino acid content of the rusks made from it at the same rate as increasing the replacement percentage compared to the control made from wheat flour only, and thus increasing the nutritional value of the resulting rusks. These results are in harmony with the work of [29] who showed that the chemical composition of toast prepared from wheat flour contains some essential amino acids that constitute such a mixture in this study. The results are in harmony with the work of [29] who explained that the chemical composition of toast bread prepared from wheat flour contains some essential amino acids, which form such a mixture in this study

Table 3. Amino acid content of formulas (g/100 g)

Amino acids (g/100g)	Chia seeds	Defatted chia	Wheat flour	Rusk control	Chia seeds rusk (%)			Defatted chia flour rusk (%)			FAO
					2	4	6	3	6	9	
Indispensable (essential) amino acids											
Valine	8.94^{b}	10.90^{a}	4.90^{c}	4.86c	4.94^{c}	5.02^{c}	5.10^{c}	10.84^{a}	10.77^{a}	10.77^{a}	1.30
Leucine	14.37^{b}	18.14^{a}	7.80^{c}	4.75^{e}	4.94d^{e}	5.13^{d}	5.33^{d}	18.02^{a}	18.45^{a}	18.45^{a}	1.90
Isoleucine	6.81^{b}	9.01^{a}	4.10$_{c}$	4.10^{c}	4.15^{c}	4.20^{c}	4.26^{c}	8.94^{a}	9.02^{a}	9.02^{a}	1.30
Threonine	8.71^{b}	10.91^{a}	3.50^{c}	2.41^{d}	2.53^{d}	2.66^{d}	2.78^{d}	10.81^{a}	11.03^{a}	11.03^{a}	0.90
Phenylalanine	10.02^{b}	13.54^{a}	4.23^{e}	5.10^{d}	10.09^{c}	10.64b^{c}	10.89^{b}	13.43^{a}	13.82^{a}	13.82^{a}	1.90
Tryptophan	1.44^{b}	1.60^{b}	1.03^{c}	1.83^{ab}	1.44^{b}	1.45^{b}	1.46^{b}	1.59^{b}	1.92^{a}	1.92^{a}	1.90
Methionine	3.59^{b}	4.50^{a}	1.62^{c}	1.47^{c}	3.54^{b}	3.50^{b}	3.46^{b}	4.47^{a}	4.88^{a}	4.88^{a}	1.70
Lysine	10.97^{b}	12.21^{a}	2.71^{d}	3.63^{c}	2.01^{e}	2.53^{d}	2.78^{d}	12.17^{a}	12.55^{a}	12.55^{a}	
Histidine	5.53^{c}	6.80^{b}	2.26^{e}	4.65^{d}	5.51^{c}	5.49^{c}	5.47^{c}	6.76^{a}	6.99^{a}	6.99^{a}	
Total indispensable A.A.	70.38^{c}	87.61^{b}	32.15^{g}	32.80^{g}	39.15^{f}	40.62^{e}	41.53^{d}	79.03^{c}	89.43^{a}	89.43^{a}	
Dispensable amino acids											

Glycine	11.99c	12.89b	3.90e	4.56d	11.84c	11.69c	11.54c	12.86b	13.01ab	13.39a
Alanine	10.91b	11.45a	3.55c	3.96c	10.77b	10.63b	10.49b	11.43a	11.76a	11.93a
Aspartic acid	16.51b	17.19a	4.13e	5.63d	16.29b	16.07b	15.85c	17.16a	17.47a	17.81a
Glutamic acid	35.11c	36.97b	37.54a	33.29d	35.07c	33.83d	33.20d	35.16c	35.50c	35.91c
Arginine	17.8b	18.33a	4.48d	2.91e	17.50b	17.20b	16.90c	18.31a	18.63a	18.91a
Serine	12.23c	13.98b	5,84f	7.10e	12.12c	12.02c	11.92d	13.84b	14.10a	14.52a
Prolin	4.82f	5.89e	11.34c	13.92a	12.67b	13.55a	13.76a	5.85e	6.01d	6.33d
Total Dispensable A.A.	109.37e	116.70b	70.78g	71.37f	116.26b	114.99c	113.66d	114.61c	116.48b	118.78a

Different letters indicate to significant difference between formulas in the same row ($P < 0.05$).

Wheat flour 72% extraction.

3.4. Rheological properties of the best rusk formulas

3.4.1. Farinograph characteristics

Table 4 shows the farinographic characteristics of the best rusk formulas. The results indicated that the highest formulas to water absorption was the formula 6% chia seeds, followed by formula 2%, then formula 6% defatted chia seeds, and the lowest was the control formula where it was 63.7, 62.4, 61.5 and 60.0%, respectively. The arrival time was least possible to the control formulas and 3% defatted chia seeds, then it increased in the formulas 6% defatted chia seeds, followed by 6% chia seeds, and was the longest possible in formula of 2% chia seeds, where it was 1.5, 1.5, 2.0, 2.5 and 7.0 minutes, respectively. The results showed that the dough development time was higher in formula of 2% chia seeds, and lower in formula of 3% defatted chia seeds, as it was after 10 and 6 minutes, respectively. Also, the stabilization time was highest in the control formula and lowest in formula 2% chia seed, where it was after 19.5 and 8.5 minutes. The degree of softness of the dough was higher in formula 2% chia seeds and lower in formulas of the control and 6% defatted chia seeds, where it was 70, 20 and 20 B.U, respectively.

Perhaps the main reason to explain these results is that all formulations contain different levels of protein, fiber and fat, which helps the dough retain more water. Moreover, dietary fiber has an amazing ability to retain water, especially soluble fiber. The dilution of gluten and the challenge of thoroughly combining fibers and wheat flour might be the cause of the prolonged dough development time (mixing time) and reduced dough stability.

Table 4. Farinograph characteristics for the best rusk formulas

Formulations	Water absorption (%)	Arrival Time (min)	Dough Development (min)	Stability (min)	Degree of softening (B.U)
Control	60.0d	1.5c	8.5b	19.5a	20.0d
Defatted chia seeds (3%)	60.8d	1.5c	6.0d	14.5c	30.0c
Defatted chia seeds (6%)	61.5c	2.0bc	8.5b	17.5b	20.0d
Chia seeds (2%)	62.4b	7.0a	10.0a	8.5d	70.0a
Chia seeds (6%)	63.7a	2.5b	7.5cd	14.5c	50.0b

Different letters indicate to significant difference between formulas in the same column ($P < 0.05$).

Control= Wheat flour 72% extraction.

3.4.2. Extensograph characteristics

The data shown in Table (5) indicate a decrease in dough extensibility, elasticity, and dough energy for the defatted chia seed formulas compared to the control sample, and the opposite occurred with the 6% chia seed formula.

Results of farinograph characteristics perhaps the main reason to explain these results is that all formulations contain different levels of protein, fiber and fat, which helps the dough retain more water. Moreover, dietary fiber has an amazing ability to retain water, especially soluble fiber. The dilution of gluten and the challenge of thoroughly combining fibers and wheat flour might be the cause of the prolonged dough development time (mixing time) and reduced dough stability. These changes are attributed to the reduction of gluten in the presence of chia seed flour, especially by increasing the mixing ratio of defatted seeds. This increasing trend indicates more stability to weakening of dough during mixing which might be due to added fiber that interacts with gluten proteins. [30] investigated how dough rheology, bread composition, and physical attributes were affected when defatted Chia seed flour was substituted for wheat flour at several percentages (5%, 10%, 15%, and 20%). According to the study, there was a substantial increase in water absorption, dough stability, dough development time, and arrival time ($P \leq 0.05$) with this substituting.

Table 5. Extensograph characteristics for the best rusk dough formulas

Formulations	Elasticity (B.U)	Extensibility (min)	P. N	Energy (cm^2)
Control	440.00^{d}	175.00^{a}	2.51^{d}	75.00^{b}
Defatted chia seeds (3%)	420.00^{e}	145.00^{c}	2.89^{cd}	60.00^{d}
Defatted chia seeds (6%)	460.00^{c}	150.00^{b}	3.06^{bc}	70.00^{c}
Chia seeds (2%)	550.00^{b}	130.00^{e}	4.23^{a}	75.00^{b}
Chia seeds (6%)	640.00^{a}	135.00^{d}	4.74^{a}	85.00^{a}

Different letters indicate to significant difference between formulas in the same column ($P < 0.05$).

Control= Wheat flour 72% extraction

P.N = Proportional number

3.5. Organoleptic properties of rusk substituted with chia seeds or their defatted flour

The results in Table (6) showed the sensory characteristics of breadcrumbs prepared from wheat flour substituted with 0, 2, 4, and 6% of chia seeds or with 0, 3, 6, and 9% of defatted chia seeds. Non-significant differences were found in most sensory characteristics between the control formula (wheat flour only) and the formula with substituting ratios of 2% chia seeds and 3% defatted chia seeds, while significant differences were found between some of the other formula ratios.

Table 6. Organoleptic properties of rusk substituted with chia seeds or their defatted flour

Treatment		Color	Taste	Flavour	Odor	Texture	Crunchy	Over all acceptability
Control		10^{a}	10^{a}	10^{a}	10^{a}	10^{a}	10^{a}	10^{a}
Chia seeds	2%	10^{a}	10^{a}	10^{a}	10^{a}	10^{a}	10^{a}	10^{a}
	4%	9^{c}	9^{b}	9^{b}	9^{c}	10^{a}	10^{a}	10^{a}
	6%	9^{d}	9^{b}	9^{b}	8^{b}	10^{a}	10^{a}	9^{b}
Defatted chia seeds flour	3%	10^{a}	10^{a}	10^{a}	10^{b}	10^{a}	10^{a}	10^{a}
	6%	9^{b}	9^{b}	9^{b}	9^{b}	10^{a}	10^{a}	9^{b}
	9%	8^{c}	9^{b}	8^{c}	8^{a}	10^{a}	10^{a}	9^{b}

Different letters indicate to significant difference between formulas in the same column ($P < 0.05$).

Control= Wheat flour 72% extraction

The results of the sensory characteristics of breadcrumbs prepared from wheat flour replaced with proportions of defatted and defatted chia flour showed non-significant differences between the control mixture and the mixtures of 2% non-defatted chia seeds, as well as the mixture of 2% defatted chia seeds. They also showed significant differences between the rest of the mixtures. The reason for this may be that increasing the substitution rate results in a darker color of rusk, in addition to an undesirable flavor and lack of crispness. [31] reported similar results while working on wheat rusks supplemented with chia flour regarding physicochemical, rheological and sensory properties.

Conclusion

The results showed that the use of substituting ratios of wheat flour with similar proportions of chia seeds, namely 0, 2, 4 and 6%, or defatted flour at proportions of 0, 3, 6 and 9%, to prepare rusks with high nutritional value. It was found that increasing the exchange rate led to enhancing the rusk content of nutrients such as protein, amino acids, crude fibers, minerals content. Increasing the substituting ratios, especially defatted chia seeds, led to an improvement in the rheological properties of the rusk dough. Also, the substitution ratios were ineffective on the sensory properties of the rusk to some extent.

4. Conflicts of interest

Authors declare no there are no conflicts to declare

5. Formatting of funding sources

The only source of financial funding for the manuscript is the author *Asmaa A. Egella* and no other authors.

6. Authorship contribution statement

This manuscript is part of the laboratory experiments performed by student *Asmaa A. Egella* to obtain her master's degree. The rest of the authors played an important role in supervising and guiding the student and writing and preparing this manuscript for publication.

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8. References

1. Vazquez-Ovando, J. Arosado-Rubio, J. G., Chel-Guerrero, L. A. and Betancur-Ancona. D. A. (2010). "Dry processing of chia (*Salvia hispanica* L.) Flour: chemical characterization of fiber and protein". CYTA - Journal of Food, vol. 8, no. 2, pp. 117-127.
2. Ixtaina, V. Y., Nolasco S. M. and Tomas M. C. (2008). Physical properties of chia (*Salvia hispanica* L.) seeds. Ind Crop Prod 28:286-293.
3. Kulczynski, B., kobus-Cisowska, J., Taczanowski, M., Kmiecik, D., Gramza-Michalowska, A. (2019). The chemical composition and nutritional value of chia seeds-current state of knowledge. Nutrients, 11(6),1242.
4. Ali, N. M., Yeap, S. K., Ho, W. Y., Beh, B. K., Tan, S. W., & Tan, S. G. (2012). The promising American Association of Cereal Chemists – AACC. (2000). Approved methods of American Association of Cereal Chemists (10th ed.). Saint Paul, Minnesota: A.A.C.C. USA
5. Baker, E. J., Miles, E. A., Burdge, G. C., Yaqoob, P., & Calder, P. C. (2016). Metabolism and functional effects of plant-derived omega-3 fatty acids in humans. Progress in Lipid Research, 64, 30-56. http://dx.doi. org/10.1016/j.plipres.2016.07.002. PMid:27496755.
6. Coelho, M. S. and Salas-Mellado M. M. (2014). Chemical Characterization of CHIA (*Salvia hispanica* L.) for Use in Food Products. J. Food Nutr. Res;2(5):263-269.
7. Ayerza, R. H. and Coates, W. (2004). Composition of chia (*Salvia hispanica* L.) grown in six tropical and subtropical ecosystems of South America. Tropical Science, 44(3), 131-135.
8. Ixtaina, V. Y.; Martmez M. L.; Spotorno V.; Mateo C. M.; Maestri D.M and Diehl B. W. K. (2011). Characterization of chia seed oils obtained by pressing and solvent extraction. J Food Comp Anal;24(2):166-174.
9. Cichon, Z. and Mi´sniakiewicz, M. (2007). Towaroznawcza Charakterystyka Pieczywa; Wyd. Akad. Ekon.: Kraków, Poland, pp. 26–27.
10. Ceglinska, A.; Cacak-Pietrzak, G.; Sobczyk, M.; Sujka, K. (2018). Wykorzystanie lecytyny w produkcji pieczywa pszennego. Prz. Zbo zowo-Młynarski, 4:32–33.
11. Jarosz, K. (2015). Kwalifikacje w zawodzie piekarz. Cz.4. Wytwarzanie ciasta oraz kształtowanie wyrobów piekarskich. PPIC, 12:12–13.
12. Corletti, E.; Byrne, C. D. (2013). Omega-3 fatty acids, hepatic lipid metabolism, and nonalcoholic fatty liver disease. Annu. Rev. Nutr. 33:231–248.
13. Bodoira, R. M.; Penci, M. C.; Ribotta, P. D.; Martínez, M. L. (2017). Chia (Salvia hispanica L.) oil stability: Study of the effect of natural antioxidants. LWT, 75:107–113.
14. Lee, A.Y.; Lee, M. H.; Lee, S.; Cho, E. J. (2017). Alpha-linolenic acid from Perilla frutescens var. japonica oil protects Aβ-induced cognitive impairment through regulation of APP processing and Aβ degradation. J. Agric. Food Chem., 65:10719–10729.
15. Caruso, M. C.; Favati, F.; Di Cairano, M.; Galgano, F.; Labella, R.; Scarpa, T.; Condelli, N. (2018). Shelf-life evaluation and nutraceutical properties of chia seeds from a recent long-day flowering genotype cultivated in Mediterranean area. LWT, 87:400–405.
16. Dabrowski, G.; Konopka, I.; Czaplicki, S.; Tanska, M. (2017). Composition and oxidative stability of oil from (*Salvia hispanica* L). seeds in relation to extraction method. Eur. J. Lipid Sci. Technol., 119, 1600209.
17. Souza, A. L.; Martínez, F. P.; Ferreira, S. B.; Kaiser, C. R. (2017). A complete evaluation of thermal and oxidative stability of chia oil. J. Therm. Anal. Calorim., 130, 1307–1315.
18. Muñoz-Tébar, N., De la Vara J. A., Ortiz de Elguea-Culebras G., Cano E.L., Molina, A., Carmona,

M. and Berruga, M. I. (2019). Enrichment of sheep cheese with chia (*Salvia hispanica* L.) oil as a source of omega- 3. LWT-Food Sci. Tech. 108: 407-415.
19. A.A.C.C. (2000). Approved methods of American Association of Cereal Chemists (10th ed.). Saint Paul, Minnesota: AACC USA.
20. A.O.A.C. (2005). Official Methods of Analysis. Association of Official Analytical Chemists. 18th edn. Washington D. C. USA; c2010. p. 172-188.
21. Pellet P. L. and Young V. R. (1980). In "Nutritional Evaluation of Protein Foods". Published by the United Nations University, pp: 546.
22. Miller, E. L. (1967). Determination of the tryptophan content of feeding stuffs with particular reference to cereals. J. Sci. Food Agric. 18(9): 381-387.
23. A.A.C.C. (1983). Approved Methods, American Association of Cereal Chemists. St. Paul, MN.
24. I.C.C (1992). International Cereal Chemistry Standard 1972 No 15 and No 114/1 (Revised 1992).
25. Kramer, A. and Twigg B. A. (1974). Fundamental of quality control for the food industry. The kulczynski, B., kobus-Cisowska, J., Taczanowski, M., Kmiecik, D., Gramza-Michalowska, A. (2019). The chemical composition and nutritional value of chia seeds-current state of knowledge. Nutrients, 11(6),1242.
26. Boriy, E. G, Yousef, E. A. and Abd Rabou, A. A. (2021). Preparation and evaluation of pan bread from chia seeds powder as substitute wheat flour. Asian food Sci. J. 20 (5): 1-10.
27. Marta, M., Pablo G., Elena, O., Francisca, H. and Francisco J. Morales (2023). Risk/Benefit Evaluation of Chia Seeds as a New Ingredient in Cereal-Based Foods. Int. J. Environ. Res. Public Health, 20, 5114.
28. Mohammed, O. B., Abd El-Razek, A. M., Bekhet, M. H. and Moharram, Y.G. (2019). Evaluation of Egyptian chia (*Salvia hispanica* L.) seeds, oil and mucilage as novel food ingredients. Egypt. J. Food Sci. 47(1):11-26.
29. El-Hadidy, G. S. (2020). Preparation and evaluation of pan bread made with wheat flour and Psyllium Seeds for Obese Patients. J. Curr. Sci. Int. 9 (2): 369-380.
30. Nassef, S. L., El-Hadidy, G. S., & Abdelsattar, A. S. (2023). Impact of Defatted Chia Seeds Flour Addition on Chemical, Rheological, and Sensorial Properties of Toast Bread. Egyptian Journal of Agricultural Sciences, 55-66.
31. Muhammad A. K., Kashif A., Sadaf S., Muhammad R. A., Madiha B., Muhammad S. K., Allah R., Madiha R., Muhammad N., Anees A. K., Neelam C., Muhammad S. and Muhammad R. (2022). Development and characterization of wheat rusks supplemented with Chia (*Salvia hispanica* L.) flour with respect to physicochemical, rheological and sensory characteristics. Food Sci. Technol, Campinas, 42, e53921, 1-10.