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Improvement of the Nutritional Value and Physicochemical Characteristics of Biscuits by Using Defatted Chia Seeds (*Salvia hispanica* L.) Flour Rich in Phytochemical Content

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Abstract

This research was performed to evaluate the effect of substitution wheat flour by ascending levels (4, 8 and 12%) of defatted chia flour (DCF) on the physicochemical properties, nutritional value, quality criteria and organoleptic evaluation of produced hard sweet biscuits. The results indicated that the crude protein and fiber contents of defatted chia flour were higher than that of wheat flour. The results revealed that biscuit samples prepared by using defatted chia flour at all substitution levels had the lowest caloric value and the highest contents of protein, lipid, ash, and crude fiber contents as compared to the control sample. Additionally, as the substitution level of wheat flour with DCF, the contents of Ca, Mg, P, Zn, and Fe were considerably ($p < 0.05$) increased. Regarding, the sensory attributes, biscuits samples particularly, those that were prepared by substituting wheat flour with 4 and 8 %were more acceptable as compared to the control which was made of wheat flour only. Based on the information provided above, it can be inferred that using defatted chia flour in bakery goods like biscuits will enhance its nutritional value and physicochemical characteristics. The created biscuits enhanced with defatted chia flour might live up to consumer expectations for wholesome and useful food.

Keywords: *Salvia hispanica* L., phytochemicals, hard sweet biscuits, minerals content, nutritional value, defatted chia flour.

1. Introduction

This research meets the need of people to eat the food they love with the same taste and quality, in addition to having high nutritional value. The food business seeks to develop innovative products that cater to consumers' desires for optimal nutrition by using functional components. In Egypt, people from all social classes view biscuits as one of the more convenient dietary items. Its widespread appeal can be attributed to its inexpensive cost, high nutritional value, diversified taste, ease of availability, and extended shelf life **[1, 2].** Biscuits are typically consumed with tea or coffee. The primary ingredients of simple biscuits are wheat flour, water, sugar, oil, and eggs. If necessary, another compound can be added to the dough **[3]**. Numerous research shown that the physicochemical characteristics of the flour and the method used to prepare it affect the nutritional, physical, and sensory aspects of biscuits **[4].** Rich protein sources can be added to cookies to make them more enriching **[5, 6].**

Consumers today want food items with high nutritional content and extra health benefits from the addition of novel ingredients and natural goods that protect against specific ailments [7]. In this regard, it may be very beneficial to produce novel functional goods by utilizing by-products from oilseeds, pseudo cereals, and other non-traditional crops **[8].** In this instance, the ancient seed chia (*Salvia hispanica* L.) has gained importance recently due to its high nutritional content **[9].** Chia seeds are an excellent source of antioxidants, dietary fiber, protein, and polyunsaturated fats including linoleic and linolenic acids **[10].** In India, chia seeds are sold commercially and are regarded as a superfood. Chia flour is regarded as a value addition to baked goods because of its nutritional qualities and ability to bind fat **[11]**. Chia seeds are a popular snack, and their purported health benefits have made them famous worldwide and have been extensively researched recently mostly due to their growing acceptance and popularity as a healthy dietary option **[12].** In addition to being used to make breakfast cereal and cookies, they are now widely utilized as dietary supplements in the US, Australia, and Latin America. 30% of vegetable oil can be found in chia seeds, which have the greatest known amount of α-linolenic fatty acid (up to 67%) **[13].** Some phytochemicals have the potential to be beneficial for the overall maintenance of the health of the organism in terms of acting as antioxidants, antimicrobials, anti-inflammatories, or as a drug or key compound for the discovery of new drugs. However, in high concentrations, some phytochemicals can act as anti-nutritional agents **[14].** It is often advised to consume plant foods high in phytochemicals due to the proven health advantages of these substances **[15,16].** This research aimed to use chia flour, which is extremely rich in phytochemicals as partial substitutes to enhance biscuits' nutritional physical and chemical properties.

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2. Materials and methods
2.1. Materials
Whole chia seeds used in this study were obtained from Abu Auf market, Nasr City, Cairo, Egypt. Ingredients used in processing of hard sweet biscuits: Wheat flour (72% extraction) 65.10%, sugar 21.40%, shortening (palm oil) 9.30%, skimmed milk powder 0.93%, high fructose syrup (42 E.D) 1.86% and vanillin extract 0.007% were obtained from the local market in Nasr City, Cairo, Egypt. Ammonium bicarbonate1.02%, sodium bicarbonate 0.37% and salt (sodium chloride) 0.013% were supplied by El-Gamhouria Industrial Chemicals and Pharmaceuticals Company, Cairo, Egypt.

2.2. Chemicals
Analytical grade solvents, chemical substances, and reagents were provided by El-Gamhouria Industrial Chemicals and Pharmaceuticals Company, Cairo, Egypt.

2.3. Methods
2.3.1. Preparation of Defatted Chia Flours (DCF):
Defatted chia flour (DCF) was produced according to the methods described by AOAC **[17]** as follows: After entire chia seeds were pulverized and their oil extracted using n-hexane in a continuous extraction device (Soxhlet) with thermal cycles at a condensation rate of five or six points per second at a temperature (80˚C, eight hours). Reduced pressure evaporation was used to remove the solvent. Ultimately, the flour obtained from the extraction oil was sieved through a 20-mesh sieve, which is the same size as the wheat flour which will be mixed. It was then packed in tightly sealed polyethylene bags and kept dry at room temperature to prevent moisture absorption until further use as described by Martinez et al. **[18].**

2.3.2. Preparation of wheat flour / Defatted chia flour (WF/ DCF) blends:
Four wheat flour/ defatted chia flour blends were prepared with the blending ratio shown in Table 1. Each flour mixture was separately mixed and homogenized, then packed in sealed tightly polyethylene bags and stored at room temperature (25±5C˚) until additional examination and processing.

Table (1): Wheat flour/ defatted chia flour blends.

Wheat Flour/ Defatted chia flour blends	Component %	
	Wheat flour (WF)	Defatted chia flour (DCF)
Control	100.0	0.00
WF/DCF1	96.0	4.00
WF/DCF2	92.0	8.00
WF/DCF3	88.0	12.00

2.3.3. Processing of biscuit:
Biscuits were prepared by using wheat flour/defatted chia flour blends (shown in Table 1) according to the method of Mesías et al. **[19].**

2.3.3.1. Hard Sweet Biscuit Preparation Procedure:
The biscuit was prepared according to AACC [20] in the following manner**:** All components were at room temperature (25±5C). First, sugar and fat were whipped together by using a lab mixer (Braun AG Frankfurt Type: KM 32, Germany, Model 2010) for ten minutes. Then dissolved sodium and ammonium bicarbonate in a small amount of water were added to the sugar and fat creamed mixture followed by the addition of high fructose syrup. Then, vanillin extract, skimmed milk powder and flour blends were added to keep the operation of mixing. To get the correct shape, the prepared dough was stretched, laminated, sheeted, extruded, moulded, and shaped continuously. An air oven was used to bake the dough pieces at 230°C for seven minutes. After baking, the biscuits were cooled for thirty minutes at room temperature (25±5ºC) before being visually inspected and sealed in polypropylene bags until further analysis.

2.3.4. Analytical methods:
.1. Chemical analysis of row material and produced biscuits:

Wheat flour (WF), whole chia seed (WCS), defatted chia flour (DCF) and hard sweet biscuits samples were subjected to the proximate chemical analysis, moisture, crude protein (N x 6.25), lipid (ether extract), ash, and fiber contents as determined by the AOAC **[17].** Carbohydrates were calculated by subtraction as follows: % carbohydrates = 100- the sum of % (crude protein + ether extract + ash + crude fiber). The results were recorded as mean± standard deviation for each examined parameter in triplicate.

.2. Caloric value:

The caloric value was calculated by using the method outlined by Paul and Southgate **[21]**as follows:
Caloric value (kcal / 100 g) = % protein ×4+ % carbohydrate × 4+ % lipid × 9).

.3. Determination of minerals content of flour blends and biscuits:

Iron (Fe), calcium (Ca), magnesium (Mg), and zinc (Zn) contents of flour blends and biscuits Samples were determined according to the AOAC **[17]** technique by using a Perkin Elmer Atomic Absorption Spectrophotometer (Varian Inc., Palo Alto, CA, USA, Model 2380). Potassium concentration was measured by using a flame photometer (CORNING 400, serial No. 4889. UK). Phosphorus was measured using a spectrophotometer and the molybdovandate procedure in compliance with the AOAC **[17].**

.4. Quantitative of phytochemical composition:

The Folin-Ciocaleau method was used to determine the total phenolic acid content of chia seeds, as highlighted by Makkar **[22].** The aluminium trichloride technique was used to calculate the total flavonoid content **[23].** The content of tannin was assessed using the Folin-Denis reagent as designated by Makkar **[22].** The total alkaloid in chia seeds was assessed by a method as described by Herborne **[24].** Total saponins were assessed by the method described by Obadoni and Ochuko **[25]**.

2.3.5. Physical properties of hard sweet biscuits:

Weight measurements of various prepared biscuits were taken using a sensitive balance (0.1g) after they had cooled for one hour at room temperature according to STUCYJOHNSON **[26]**. Biscuit diameter (W) and thickness (T) were measured as described by Nayani and Rao **[27].** The average diameter/thickness was used to calculate the spread ratio (W/T) **[28].**

2.3.6. Organoleptic evaluation of hard sweet biscuits produced:

To ascertain customer acceptability, twenty panellists from the Food Science and Technology department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt, took part in the sensory evaluation of biscuit samples. Ample time was allowed to prevent any misunderstandings. The standard recipe which is processed from wheat flour (72% extraction) was used as the control. All samples were coded to avoid any bias. The evaluated biscuit samples were presented in a randomized manner, and each panellist was asked to indicate their preferences for appearance, color, taste, odor, hardness, crispiness, texture, and overall acceptability. The assessment was carried out in the afternoon, five hours after breakfast. Water was available for panellists to rinse their mouths following the evaluation of each sample throughout the panel test. Each product's quality acceptance was rated as excellent, very good, good, or poor depending on the mean of the overall score **[29].**

2. 3.7. Statistical analysis:

Three replicates of each experiment were conducted. The data was analyzed statistically utilizing the Statistics Package for Social Science (SPSS) software (versioning 20.0, created by IBM Software, Inc., Chicago, Illinois, United States, 2018), following the guidelines of Gomez and Gomez **[30],** for a completely randomized design. For every result, the mean ± standard errors (SE) were shown. The statistical analysis was completed at a significant level of 5% using a one-way analysis of variance (ANOVA). Then, Duncan various range tests were performed ($p < 0.05$).

3. Results and Discussion

3.1. Chemical properties of raw materials:

3.1.1. Proximate composition and caloric value of the whole chia seeds:

The chemical profile and caloric value of whole chia seeds (WCS) are shown in Table (2). The results revealed that the moisture content of (WCS) was low (7.13%). This keeps the seeds' quality intact during storage in suitable conditions, as the growth of microorganisms and metabolic reactions are often inhibited at this moisture level. Additionally, the low moisture content is reflected in high dry matter content more than 90% of **[31].** These findings coincide with those of Ixtaina et al. **[32],** Mohammed et al. **[31]** , and Aguirre et al**. [33]**, who explained that the water content of chia seeds was 6.80%.

Also, the same Table demonstrates the high nutrient content of whole chia seeds, with relative dry basis contents of 17.35, 21.57, and 28.14 g/100 g for crude fiber, protein, and lipids, respectively. The findings of Coelho and Salas-Mellado **[34],** Suri et al. **[35]**, and Guiotto et al**. [36]** are consistent with these results, which show that whole chia flour has high dietary fiber, protein and fat contents. The results shown in Table (2) indicated that the whole chia seeds had a significant carbohydrate content of around 29.66% on a dry weight basis. From the explanation above, the main constituent of chia seeds is carbohydrates, which is followed by lipids, proteins, fibers and ash, in that order. Chia seeds are therefore one of the new sources of oil seeds. The data also indicated that the caloric value of 100g of whole chia seeds (WCS) is 458.18 kcal. Chia seeds have a high-calorie content that may be explained by their high carbohydrate, protein and lipid contents, besides that it a significant source of essential fatty acids and fat-soluble vitamins (A, D, E, and K). The current result was less than the 519.9 kcal/100g caloric value of chia seeds published by Coelho and Salas-Mellado **[37].** Conversely, our findings align with the outcomes of Martínez et al. **[38].** The proximate composition of whole chia seeds has been determined through previous research, and the results generally agree with those of Goh et al. **[39]** and Fernandes and Salas-Mellado **[40],** who reported that the contents of chia seeds were 30-33% oil, 15-25% protein, 26-41% sugars, high in fiber from the diet (18-30%), 4-5% ash, and 90-93% dry matter.

Table (2). Proximate composition and caloric value of the whole chia seeds.

Compounds (g/100g)	Whole chia seeds (WCS)*	
	W/W	D/W
Moisture content	7.10	--------
Protein **	20.03±0.16[b]	21.57±0.18[a]
Lipids	26.15±0.23[b]	28.14±0.34[a]
Crude fiber	16.09±0.18[b]	17.35±0.21[a]
Ash content	3.26±0.19[b]	3.28±0.17[a]
carbohydrates ***	27.37±0.52[a]	29.66±0.35[b]
Caloric value (kcal/100g)	424.95±0.61[b]	458.18±0.59[a]

*W/W: on wet weight D/W: on dry weight, **N =6.25 *** Carbohydrates were calculated by difference. M±SE: Means± standard error for chemical composition; the means within the same row having different superscripts are significantly varied ($P \leq 0.05$).

3.1. 2. Phytochemical contents of chia seeds:

Figure (1 and 2) exhibits the total phenolic acid, flavonoids, tannins, saponins, and alkaloids concentrations. The results showed that chia seeds are very rich in phenolic acid, flavonoids, tannins, saponins, and alkaloids contents, which were 96.75±0.95 mg GAE/g of dry weight, 410.27±2.37 mg RTE/g of dry weight, 85.85±0.69 mg TAE/g of dry weight, 4.25 mg /100 g dry weight, and 7.47 mg /100 g dry weight, respectively. Phenolic acids, flavonols, and flavonoids are known for their powerful antioxidant properties and their ability to bind to proteins, thus inhibiting amylase activity. Hence, it has been observed to regulate the glycemic index of food products and participate in the cellular defence mechanism against free radicals, leading to the alleviation of excessive oxidative stress in human cells during unfavourable conditions **[41-43]**. Those results indicate that the seeds of *S. hispanica* exhibit strong nutritional quality and rich phytochemical properties that are beneficial to health.

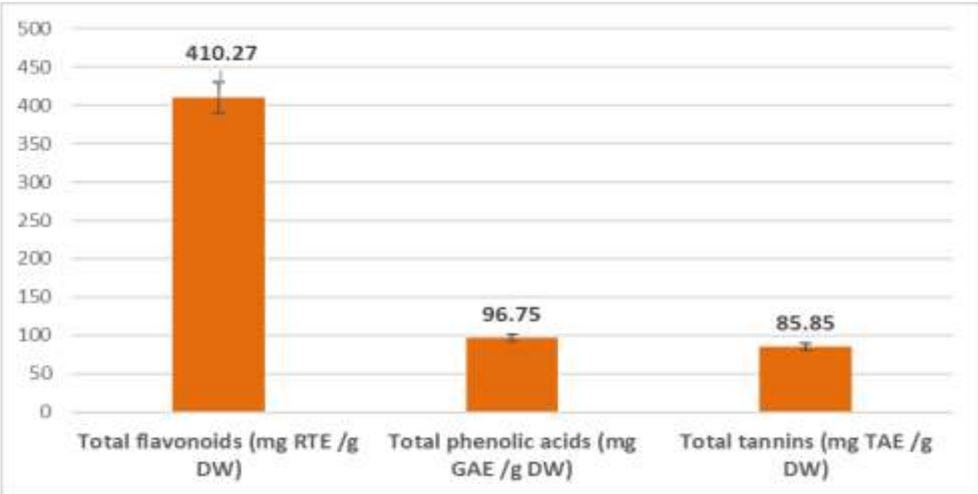

Fig. (1). Total flavonoids, phenolic acids, and tannins contents of chia seeds

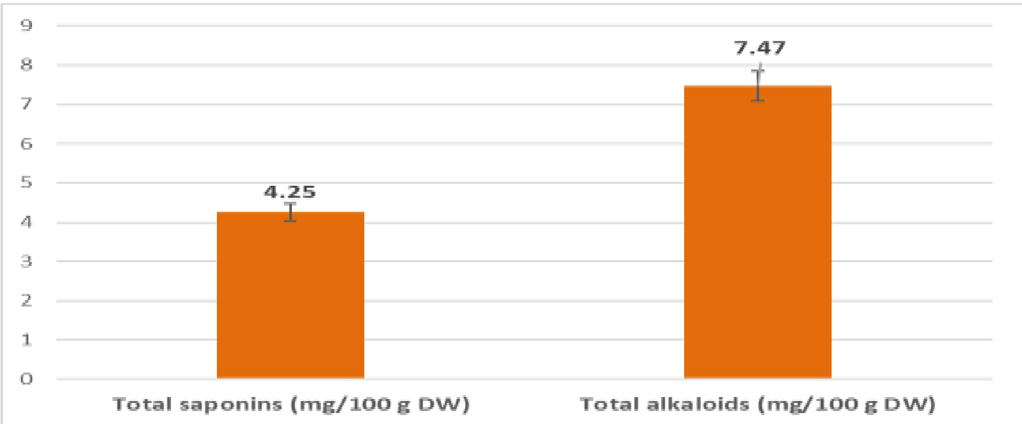

Fig. (2). Total saponins and alkaloids contents of chia seed

3.1.3. Proximate composition and caloric value of wheat flour (WF) and defatted chia seeds flour (DCF):

Table (3) lists the chemical components of defatted chia flour (DCF) in comparison to wheat flour (WF). The obtained result showed that wheat flour (WF) contained lower protein content (10.58%) as compared to defatted chia flour (DCF) (29.80 %). On the other hand, defatted chia flour had a higher amount of crude fiber which was recorded at 23.86 % versus 0.97% for wheat flour. These findings are near to those obtained by da Silva Marinelli et al. **[44],** who found that leftover meals from defatted chia contain high protein (33.9–39.9%) and fiber contents (19–23%). The results displayed in Table (3) cleared that WF and DCF lipid contents were nearly around the same range (0.89–0.97%). Regarding, carbohydrates wheat flour contains more than twofold that of defatted chia flour, 86.88 and 40.65%m respectively. It was also possible to see from the same Table that the ash content of DCF was significantly higher than that of wheat flour, 4.72 and 0.68 %, respectively. These results on line with that of Anderson et al. **[45]**, Coelho and Salas-Mellado **[34]**, and Guiotto et al. **[36]**, who indicated that defatted chia flour had high levels of dietary fiber and ash, while their lipid content significantly decreased ($p < 0.05$).

On the contrary, wheat flour (WF) had a higher caloric value (397.85 kcal/100g) than that of defatted chia flour (290.53 kcal/100g).

Table (3). Chemical composition and caloric value of wheat flour (WF) and defatted chia seeds flour (DCF): (on dry weight basis).

Compounds (g/100g)	Raw Material	
	Wheat flour (WF)	Defatted chia flour (DSF)
Moisture	12.21±0.10^{b}	6.76±0.11^{a}
Crude protein	10.58±0.19^{b}	29.80±0.17^{a}
Lipids	0.89±0.16^{ab}	0.97±0.23^{a}
Crude fiber	0.97±0.12^{b}	23.86±0.12^{a}
Ash content	0.68±0.11^{b}	4.72±0.11^{a}
Carbohydrates*	86.88±0.20^{a}	40.65±0.19^{b}
Energy value (kcal/100g)	397.85±0.44^{a}	290.53±0.56^{b}

* Carbohydrates were calculated by subtraction. M± SE: Means± standard error for chemical composition; the means within the same row having different superscripts are significantly varied ($P \leq 0.05$).

3.2. Mineral content (mg/100 g) of wheat flour (WF) and defatted chia seeds flour (DCF):

The primary macro and microelements (bio-elements) of defatted chia flour (DCF) and wheat flour (WF), such as iron (Fe), zinc (Zn), phosphorous (P), calcium (Ca), and magnesium (Mg) have been determined and detailed in Table (4). The data showed that the wheat flour had lower contents of calcium (43.82 mg/100 g), phosphorous (178.94 mg/100 g), magnesium (82.96 mg/100 g), zinc (2.19 mg/100 g), and iron (2.75 mg/100 g) as compared to defatted chia flour which had the following contents; 646, 812, 277, 5.19 and 13.16, respectively.

Consequently, the mineral content of wheat flour was less than that of the reference pattern of the recommended daily allowances . **[46].** These results are consistent with those of Nadir et al. **[49]**, who found that wheat flour contains 2.66 mg/100 g of iron, 87.92 mg/100 g of magnesium, 41.76 mg/100 g of calcium, and 2.15 mg/100 g of iron on a dry weight basis.

Table (4). Mineral contents of wheat flour (WF) and defatted chia seeds flour (DCF):.

Mineral (mg/100g)	Wheat flour (WF)	Defatted chia flour (DCF)
	Macro elements	
Calcium (Ca)	43.82	646
Phosphorus (P)	178.94	812
Potassium (K)	143.81	442
	Microelements	
Magnesium (Mg)	82.96	277
Zinc (Zn)	1.19	5.19
Iron (Fe)	1.75	13.16

3.3. Effect of replacing wheat flour with defatted chia flour (DCF) on quality criteria of biscuit samples:

3.3.1. Chemical composition of biscuits samples:

The chemical composition of biscuit samples processed from wheat or wheat flour / defatted chia flour blends, which is prepared by replacing wheat flour with defatted chia flour (DCF) with the following replacing levels;4, 8, and 12% is tabulated in Table (5). Table (5) showed that there was a significant ($p < 0.05$) increase in the amounts of protein, lipid, ash, and crude fiber as well as a decrease in the content of carbohydrates in the formulas that included defatted chia flour (DCF) as compared to the control sample. The results exhibited that the control sample had the highest carbohydrate content and the lowest levels of protein, fat, ash, and fiber among all biscuit samples. When the DCF replacement levels were increased from 4% to 12%, The crude protein content of biscuits increased as the replacing of WF with DCF increased, since the highest protein content was

noticed for WF/DCF3 biscuits sample formulated with 88% WF/12% DCF, 16.21%, as compared to 9.86 % for the control sample. These results concurred with those of López et al. **[48]** and Jimenez et al. **[47],** who discovered that bean, chia, and amaranth flour could replace wheat flour and that the resulting bakery goods had notable contents of fiber, protein, and fats. Additionally, Oliveira et al. **[50]** showed that the high fiber, protein, mineral, and lipid content of chia flour makes it a viable option for adding extra nutrients to baked goods. The results shown in the same Table indicate a little increase in the fat content of the biscuits after replacing wheat flour with DCF. This may be explained by the chia seed fibers potent ability to bind oil. These findings are consistent with those of Goyat et al. **[51],** who found that the content of ether extract in cookies fabricated with chia flour replacements did not significantly increase. Furthermore, compared to the control sample the partial substitution of wheat flour with DCF resulted in a significant ($p < 0.05$) increase in biscuits' crude fiber content. Since, when the substituting level was raised from 4.0 to 12.0% in the tested samples with DCF, the fiber content increased from 3.62% to 8.83% for WF/DCF1 and WF/DCF3 biscuits, respectively, in comparison to the control sample (0.99%). The high dietary fiber intake reduces the chance of acquiring diabetes, obesity, cardiovascular disease, and hypertension, among other disorders **[45].** These results on line with those of Mesías et al. **[19]** and Goyat et al. **[51]** who reported that the amounts of protein, dietary fiber, antioxidants, and unsaturated fatty acids in biscuits samples formulated by replacing wheat flour with defatted chia seed flour.
Table (5), however, demonstrates a progressive decrease in the amount of carbohydrates with an increase in the level of substituting wheat flour with defatted. Chia flour since the carbohydrate contents of the biscuits sample were 7.71, 70.25, 65.56, and 60.35 for control, WF/DCF1, WF/DCF2 and WF/DCF3, respectively.
These findings support the findings of Goyat et al. **[51]** Aguirre et al. **[33]**, and Guiotto et al. **[36],** found that baked items with a larger percentage of defatted chia flour had fewer carbohydrates.
Table 5, also shows that there is a significant difference in calorie values (Kcal/100g) between the control biscuits sample and that containing DCF ($p < 0.05$). Notably, when the replacement level is raised, the DCF samples' caloric values of DCF-containing biscuit samples are reduced ($p < 0.05$). The caloric values of the biscuit samples decreased from 442.08 for the control sample to 413.34 Kcal/100g for WF/DCF3 Table (5), clearly shows that biscuit samples formulated with DCF at any substitution levels (4, 8, and 12%) were had the lower calorie values and the higher values of nutrients including protein, ash, and crude fibre contents as compared to control.

Table (5). Chemical composition (%) of hard sweet biscuits* prepared by substituting wheat flour (WF) with defatted chia flour (DCF) (on dry weight basis).

Component (g/100g)	**Control**	**WF/DFC1**	**WF/DFC2**	**WF/DFC3**
Crude protein	9.86 ± 0.18^{c}	12.98 ± 0.14^{b}	14.97 ± 0.12^{a}	16.21 ± 0.11^{a}
Ether extract	10.20 ± 0.26^{b}	11.36 ± 0.63^{ab}	11.50 ± 0.22^{ab}	11.90 ± 0.34^{a}
Crud fiber	0.99 ± 0.21^{d}	3.62 ± 0.46^{c}	5.98 ± 0.13^{b}	8.83 ± 0.54^{a}
Ash content	1.24 ± 0.11^{b}	1.79 ± 0.17^{ab}	1.99 ± 0.63^{ab}	2.71 ± 0.18^{a}
Carbohydrates	77.71 ± 0.24^{a}	70.25 ± 1.32^{b}	65.56 ± 0.74^{c}	60.35 ± 1.22^{d}
Energy value (kcal/100g)	442.08 ± 1.22^{a}	435.16 ± 0.83^{b}	425.62 ± 1.19^{c}	413.34 ± 1.15^{d}

* Control=100%WF, WF/DFC1= 96%WF/4%DCF, WF/DCF2= 92%WF/8%DCF and WF/DCF3= 88%WF/12%DCF.

3.4. Minerals contents of biscuits samples:

Table (6), lists the mineral contents of biscuits samples formulated from wheat flour and wheat flour/defatted chia flour blends. The results showed that the Ca, Mg, P, Zn, and Fe content of biscuits increased significantly ($p < 0.05$) as the replacement level of wheat flour increased. In the context, Zn content is increased with increasing the substitution of wheat flour with DCF, since Zn contents were 1.98,2.99,5.43 and 6.62 for control, WF/DCF1, WF/DCF2 and WF/DCF3, respectively. The results revealed that WF/DCF3 had the highest content of any mineral with the following contents; 129.83, 319.89,161.93, 155.15,7.53and 6.62 mg/ 100g for Ca, P, K, Mg, FE and Zn, respectively, while control sample was had the lowest content of any mineral with the following contents; 39.84,118.89,146.81,66.87,2.48, and 1.98 mg /100g for Ca, P, K, Mg, FE and Zn, respectively. These results are supported by those of Oliveira et al. **[50]** and Goyat et al**. [51]**, who showed that chia flour can be utilized to improve the nutritional content of baked goods because it is high in fiber, protein, minerals, and lipids.

Table (6). Minerals content of hard sweet biscuits* prepared by substituting wheat flour (WF) with defatted chia flour (DCF) (on dry weight basis).

Mineral content (mg/100g)	**Control**	**WF/DFC1**	**WF/DFC2**	**WF/DFC3**	**RDA** (mg/day)**
Calcium (Ca)	39.84	57.85	96.38	129.83	800-1200
Phosphorus (P)	118.89	174.98	262.89	319.89	800-1200
Potassium (K)	146.81	150.81	157.83	161.93	2000-4000
Magnesium (Mg)	66.87	87.89	121.95	155.15	280-350
Iron (Fe)	2.48	4.59	5.02	7.53	8-10
Zinc (Zn)	1.98	2.99	5.43	6.62	10-12

* Control=100%WF, WF/DFC1= 96%WF/4%DCF, WF/DCF2= 92%WF/8%DCF and WF/DCF3= 88%WF/12%DCF. ** Recommended Dietary Allowances reported from Food and Nutrition Board**, (1989).** The means within the same column that have distinct superscripts exhibit a significant difference ($P < 0.05$).

3.5. Effect of replacing wheat flour with defatted chia flour (DCF) on physical properties of biscuit samples:
Table (7), demonstrated that the replacing of wheat flour (WF) with defatted chia flour (DCF) had a significant ($p < 0.05$) impact on the biscuits' physical attributes, including spread ratio, thickness (T), and diameter (D). The results illustrated the weight of the biscuit sample was progressively raised concerning the control sample by increasing the DCF incorporation level, the average weight of the biscuit samples was as follows; 7.06, 7.25, 7.41 and 8.01g for the control, WF/DCF1, WF/DCF2 and EF/DCF3, respectively. These findings concurred with those of Singh et al. **[52],** who demonstrated that the higher fiber content of chia flour may be responsible for the rise in cookie weight.

As can be seen in the same table, there were notable differences ($p <0.05$) between the average diameter of the control since it reduced in the biscuits sample formulated with substituting wheat flour with defatted chia flour, the reducing average diameter is increased with increasing substituting level of WF with DCF, as the average diameter values were 6.75, 5.96, 5.78 and 5.15 cm for control, WF/DCF1, WF/DCF2 and WF/DCF3, respectively.

Similarly, the thickness of biscuits was reduced as the replacing level of WF with DCF was increased since it reduced from 0.78 cm for control to 0.75, 0.73and 0.68 cm for WF/DCF1, WF/DCF2 and WF/DCF 3, respectively.

The spread ratio, which was computed by dividing the biscuit samples' diameter (D) by thickness (T), reflects changes in both width and thickness. It is a crucial measure for estimating how the dough will behave after baking. A larger diameter and a better spread factor are seen to be essential biscuit quality attributes **[53].** Despite suggestions that the amount of gluten, sugar, or fiber may have an impact on the spread factor **[54].** The control sample's spread ratio was 8.65; which is reduced by increasing the replacing level of WF with DCF to 7.94, 7.91 and 7.57 for WF/DCF1, WF/DCF2 and WF/DCF3, respectively. These findings are consistent with those of Goyat et al. **[51]** and Makpoul and Ibrahim **[55]**. In general, it can be observed that when the substitution level of DCF is increased from 4.0 to 12%, the biscuits' diameter, thickness, and spread ratio decrease in comparison to the control sample.

Table (7). Physical properties of hard sweet biscuits* prepared by substituting wheat flour (WF) with defatted chia flour (DCF).

physical properties	Control	WF/DFC1	WF/DFC2	WF/DFC3
Weight (g)	7.06 ± 0.25^{a}	$7.\ 25\pm0.19^{a}$	7.41 ± 0.85^{a}	8.01 ± 0.61^{a}
Diameter (D) (cm)	6.75 ± 0.53^{a}	5.96 ± 0.67^{ab}	5.78 ± 1.13^{ab}	5.15 ± 0.62^{b}
Thickness (T) (cm)	0.78 ± 0.11^{a}	0.75 ± 0.44^{a}	0.73 ± 0.67^{a}	0.68 ± 0.36^{a}
Spread ratio (D/T)	8.65 ± 0.85^{a}	7.94 ± 0.75^{ab}	7.91 ± 0.58^{ab}	7.57 ± 1.41^{b}

* Control=100%WF, WF/DFC1= 96%WF/4%DCF, WF/DCF2= 92%WF/8%DCF and WF/DCF3= 88%WF/12%DCF. The means within the same column that have distinct superscripts exhibit a significant difference ($P < 0.05$).

3.6. Effect of replacement wheat flour with defatted chia flour (DCF) on sensory evaluation of hard sweet biscuit samples.

Evaluating food products with the senses is essential to define their quality. The consumer also has a big say in what products are chosen. Pereira et al. **[56]** list taste, texture, odor, and surface color as some of the essential characteristics linked to quality. When biscuits with varying amounts of defatted chia flour (DCF) were compared to the control sample, their organoleptic quality attributes (appearance, color, taste, flavor, hardness, crispness, texture, and overall acceptability) were assessed. The results are given in Table (8). The results indicated that there were no significant variations in most of the sensory qualities between the control sample and the biscuit sample that included DCF at levels 4 and 8%. These findings are consistent with those of Rendón-Villalobos et al. **[7],** who demonstrated that adding whole chia seed powder instead of 15% maize flour enhanced the nutritional content of tortillas without affecting their sensory qualities.

Conversely, as compared to the control sample and other biscuit samples, the samples with 12% DCF showed significant differences ($P <0.05$) in all sensory attributes and somewhat lower judging scores. Overall, the results indicated that biscuits made by replacing wheat flour with defatted chia flour had better acceptability and good sensory qualities when compared to the control biscuit sample made with 100% wheat flour, particularly when the substitution levels were increased to 8% However, the biscuits produced with the highest substitution level (12%) scored the lowest scores. According to Nazni and Pradeepa **[57]**; Eke-Ejiofor **[58] and** Soliman et al. **[59],** the number of ingredients and biscuit preparation recipes may have an impact on sensory qualities, customer preference, and acceptance.

Table (8). Sensory evaluation of biscuits prepared from wheat flour or wheat flour (WF) substituted by defatted chia flour (DCF).

Biscuit Samples	Sensory properties*									Grade
	Appearance (10)	Color (10)	Taste (10)	Odor (10)	Hardness (10)	Crispness (10)	Texture (10)	Overall accept. (30)	Total scores (100)	
Control	8.70±0.65[a]	8.82±0.56[a]	8.50±0.32[a]	8.70±0.27[a]	8.20±0.36[a]	8.73±0.70[a]	8.82±0.17[a]	28.25±0.65[a]	88.72	Excellent
WF/DCF1	8.50±0.23[a]	8.40±0.43[ab]	8.40±0.34[a]	8.50±0.23[a]	8.10±0.11[a]	8.30±0.43[a]	8.40±0.22[ab]	27.00±0.87[b]	85.60	Excellent
WF/DCF2	8.40±0.11[ab]	8.10±0.56[b]	8.20±0.22[a]	8.10±0.29[ab]	8.00±0.21[a]	8.00±0.54[ab]	8.20±0.14[ab]	26.50±0.67[b]	83.50	Very Good
WF/DCF3	7.00±0.16[b]	7.20±0.33[b]	7.70±0.18[a]	7.60±0.12[b]	7.00±0.32[b]	7.10±0.12[b]	7.20±0.13[c]	23.00±0.54[c]	74.00	Good

* Means ± standard error of three determinations The means within the same column that have distinct superscripts exhibit a significant difference ($P < 0.05$). Grade: 85-100 (Excellent), 75-85(Very Good), 60-75 (Good), Less than 60 (Poor).

4. Conclusion

Finally, it could be concluded that defatted chia flour can be a useful alternative, for some wheat flour in baked products (biscuits) since it is a useful source from all aspects of health and nutrition as well as economically and is easily accessible to various nutrients that enhance the nutritional value. DCF is rich in many secondary metabolites, some of which are used to improve general health and treat some health problems, such as flavonoids, alkaloids and saponins. Biscuits formulated by replacing wheat flour with defatted chia flour with a level of up to 12% of wheat flour exhibited higher nutritional content and better sensory acceptability than biscuits based solely on wheat flour. As a result of the replacement, the amount of micronutrients such as minerals, fat, dietary fiber and protein was increased significantly. Furthermore, the results showed that replacing up to 8% of wheat flour with defatted chia flour resulted in satisfactory sensory properties. It can also be nominated as an addition to some other foods that depend on their manufacture of wheat flour. Lastly, it is important to study the use of these innovative functional raw materials in other products by evaluating their qualities and sensory attributes that meet customer expectations.

Declaration of conflicting interests

There are no possible conflicts of interest that the authors have disclosed about the research, writing, or publication of this article.

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