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Nutritional and Sensory Evaluation of Bread Fortified with Defatted Chia Flour

Noor-us-Sana[1], Muhammad Sibt-e-Abbas[2*], Muhammad Usman[3], Rimsha Umar[2], Anam Arif[1]

Abstract

Nutritional awareness among consumer is increasing along with their life styles changes day by day. Bread is the most popular product that can be enriched with various seeds *i.e.* chia seeds that are known for their high nutritional value. Defatted chia seeds serve as excellent protein source and often used to boost the nutritional content of bread. In this study, bread was fortified with 2%, 4%, and 6% defatted chia flour, which significantly improved its overall nutritional profile. Addition of defatted chia flour up to 6% is acceptable to consumer. Results showed that color of defatted chia flour bread was slightly darker than normal bread. Addition of defatted chia flour in bread made it easily breakable with firmer texture. Texture of chia bread was less chewy and sticky as compared to normal wheat bread. The addition of defatted chia flour increased protein content to 12.18±0.02%, 14.75±0.06%, and 16.94±0.04% in T_1, T_2, and T_3 as compared to simple wheat bread *i.e.* 10.85±0.08%. Likewise, total phenolic contents increased to 2.70±0.23%, 33.63±0.27%, and 4.20±0.13% in T_1, T_2, and T_3 of defatted chia bread from 1.45±0.05% in simple wheat bread. Overall, addition of defatted chia seed powder enhanced the nutritive value of bread remarkably.

Keywords: Defatted Chia Seeds**,** Nutritional bread, Dietary fiber, Sensory profile, Protein fortification

1. Introduction

Malnutrition remains a critical global issue, especially among children during their early development stages when their brains are still undergoing rapid growth and development. Deficiencies in essential nutrients during these stages can significantly impair memory, cognitive development and behavior with long-term consequences. Studies have shown that inadequate nutrition during pregnancy and early childhood correlates with reduced cognitive and memory function, especially in resource-constrained populations. People believe that the growth of the brain and intelligence rely on three important things: genes you are born with, a good environment to learn in, and eating the right kinds of foods (Adamczyk *et al*, 2021).

Food scientists are continuously working to develop optimal food formulations that cater to consumers' growing demand for natural, nutritious, and functional foods. Bread, a widely consumed staple, is providing a

[1] Department of Food Science & Nutrition, TIMES Institute Multan, Pakistan.
[2] Department of Food Science & Technology, MNS-University of Agriculture, Multan, Pakistan
[3] Department of Human Nutrition and Dietetics, MNS-University of Agriculture, Multan, Pakistan
[*]Corresponding author's E-mail: sibte.abbas@mnsuam.edu.pk
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convenient and versatile source of nutrition. One approach to enhancing its nutritional profile is by fortifying it with nutrient-dense ingredients such as seeds (Adamczyk *et al.,* 2021). However, for a healthier lifestyle, it is recommended to include whole grain bread in the daily diet due to its higher fibre and nutrient content (Sayed-Ahmad *et al.,* 2018).

The rising demand for healthy and nutritious foods among consumers has pushed the food industry to explore and harness its resources to develop functional ingredients. Recently, wheat bread and other bakery products have been enriched with innovative ingredients to improve their nutritional value (Adamczyk *et al.,* 2021). Many studies have shown that making simple changes to our diet, such as including more whole grains, seeds, high-fiber foods, and omega-3 fatty acids, can help reduce cholesterol and lower the risk of serious conditions like coronary artery disease (Iglesias *et al.,* 2013). This emphasizes how powerful food choices can be in shaping our overall health.

Chia seeds *(Salvia hispanica)*, part of the *Lamiaceae* family, have been used as a nutritional staple for centuries, especially in the diets of ancient civilizations in Central and South America. What makes chia special isn't just its historical roots but its incredible nutritional profile, which has made it a modern-day superfood. In today's world, chia seeds have become highly sought after, not only for rich omega-3 content but also for high fiber, protein, and antioxidant levels (Madruga *et al.,* 2020). Chia has found its way into a variety of foods, from snacks like cookies and breakfast cereals to health supplements, reflecting its versatility.

Chia seeds offer a broad range of essential nutrients *i.e.* around 30% oil, with high concentration of alpha-linolenic acid, 20-26% protein, 3-5% ash, 25-40% carbohydrates, and a substantial amount of dietary fiber (17-29%), which is essential for maintaining digestive health and reducing cholesterol and blood sugar levels (Rendón-Villalobos *et al.,* 2012). Moreover, after oil extraction, chia seed meals still retain considerable nutritional value. The remaining fiber content is about 19-23%, while protein levels range from 34-40%, along with a rich presence of antioxidants (Jiménez *et al.,* 2019).

Incorporating chia flour into bread recipes not only improves its nutrient density but also offers potential health benefits. Regular consumption of chia-enriched bread may support cardiovascular health, promote better digestion, and help maintain healthy cholesterol and blood sugar levels. This research explores the effects of defatted chia flour (2%, 4%, and 6%) to bread, examining how it enhances the overall nutritional value without compromising its sensory qualities. By integrating chia seeds into bread, we aim to create a product that not only meets consumer demands for healthier options but also contributes to improve public health. The purpose of this study was to assess the effects of adding defatted chia flour to bread in order to boost its nutritional profile.

2. Materials and Methods

The present study was conducted at Postgraduate Research Laboratory of TIMES Institute Multan undertaking a Nutritional and Sensory Evaluation of Wheat-based Bread Fortified with Defatted Chia Flour. The following approaches and processes are described in detail:

2.1. Procurement of raw materials

Chia seeds (*Salvia hispanica L.)* and other ingredients (wheat flour, sugar, salt, and dry yeast) were acquired from a local store in Multan. The chemicals & standards including those used in proximate and phenolic analyses were bought from Merck (Merck KGaA, Darmstadt, Germany) and Sigma-Aldrich (Sigma-Aldrich Tokyo, Japan).

Table 1 Composite flour treatments

Treatments	Wheat flour (%)	Chia flour (defatted %)
T_0	100	0
T_1	98	2
T_2	96	4
T_3	94	6

2.2. Preparation of raw material

The chia seeds were cleaned thoroughly prior to grinding into fine powder that was used for further analyses.

2.3. Proximate analysis

Chia seeds and wheat flour were initially analyzed for proximate composition including moisture, crude fat, crude protein, ash crude fiber and nitrogen free extract (NFE) (AACC, 2000; AOAC, 2006).

2.4. Measurement of Total Phenolic Content

The total phenolic content (TPC) of chia seeds was assessed spectrophotometrically by applying a modified Folin-Ciocalteu method (Sayed-Ahmad *et al.,* 2018)

2.5. Defatting of chia seeds

Ground chia seeds were defatted by extracting oil using conventional solvent (hexane) in a soxtec system (Model: H-2 1045 Extraction Unit, Hoganas, Sweden) (AOAC, 2006). The defatted chia seeds were dried prior to storage for further use.

2.6. Composite flour development

Defatted chia seeds flour was used to replace wheat flour to prepare different blends of composite flour with substitution levels of 2%, 4% and 6% as mentioned in Table 1.

2.7. Pan bread processing

The straight dough process was performed in pan bread preparation according to the method described by El Hadidy (2020). The materials were: 100 g Wheat flour, 1.5 g instant active dry yeast, 2.0 g sugar, 2.0 g salt, 3.0 g shortening and water. Formulas containing defatted chia flour as partially substitute for Wheat flour at different extents (0, 2, 4 and 6%) were placed in a mixing bowl to mix for 6 minutes at 28 ± 2.0°C. The formulated dough was rounded manually by folding for 20 times and then left to rest for 10 minutes. The prepared dough was placed in baking pans and left in a cabinet for proofing at 30 ± 0.5 °C and 85% relative humidity for 80 minutes. Furthermore, the dough was baked at 250 °C for 20 minutes. Finally, the baked bread was cooled at room temperature (25 ± 2.0 °C) for 60 minutes and then packed in polyethylene bags for further analyses.

2.8. Chemical characteristics

2.8.1. Proximate Analysis

The levels of ash, minerals, crude protein, fat, fiber, moisture were analyzed using standard method (AOAC, 2006), and nitrogen-free extract was analyzed using (AACC, 2000) method.

2.8.2. Measurement of Total Phenolic Content

The total phenolic content (TPC) was assessed spectrophotometrically by applying a modified Folin-Ciocalteu method (Sayed-Ahmad *et al.,* 2018). Phenolic compounds were first extracted using a methanol-water mixture, followed by filtration to remove solid residues. A calibration curve was prepared using gallic acid as a standard. For the reaction, 1 mL of the sample extract was mixed with 5 mL of 10-fold diluted Folin-Ciocalteu reagent and allowed to react for 3 minutes. Then, 4 mL of 7.5% sodium carbonate solution was added, and the mixture was incubated at room temperature for 2 hours in the dark. Absorbance was measured at 765 nm using a UV-Vis spectrophotometer, and TPC was expressed as milligrams of gallic acid equivalents per gram of sample (mg GAE/g).

Table 2 Proximate Composition (%) and TPC of Raw Materials (100g)

Parameter	Wheat Flour	Defatted Chia Flour
Moisture content	12.5±0.06	7.6±0.05
Crude Protein	11.7±0.31	26.5±0.44
Crude fat	1.5±0.12	32.8±0.13
Crude fibre	3.10±0.13	23.5±0.94
Ash	0.45±0.05	4.10±0.08
NFE	70.75±0.14	5.5±0.12
TPC (mg GAE/g d.m.)	0.65±0.06	5.70±0.26

2.9. Physical characteristics

2.9.1. Color analysis

The crumb color of the bread was assessed using the L*, a*, and b* color values, which are standard for evaluating the appearance of food products. The color measurements were taken using a HunterLab MiniScan XE Plus colorimeter (Sayed-Ahmad *et al.,* 2018). While the color difference was calculated using the following formula:

$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

2.9.2. Textural profile

The texture of bread was analyzed with the assistance of the TA.XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK). We followed the Standard Procedure for Firmness and Elasticity from the American Institute of Baking (located in Manhattan, KS) as elaborated by Shearer and Davies (2005). This texture analyzer is automatic equipment with software attached that shows values of texture parameters (Sayed-ahmad *et al*, 2018).

2.9.3. Volume

The bread's volume was determined using the displacement method, where the volume of displaced seeds indicated the bread's size (AACC, 2000). A container of known volume was partially filled with small seeds, and the initial seed level was recorded. The bread sample was carefully placed into the container, displacing the seeds to a new level. The volume of the displaced seeds was measured as the difference between the initial and final seed levels. Care was taken to minimize gaps or voids by gently tapping the container during measurement. Bread volume was expressed in cubic centimeters (cm^3).

2.9.4. Sensory Evaluation

The sensory characteristics were assessed using 9-point hedonic scale (Meilgaard *et al.,* 2007). The training was done to teach 9 people (aged 25 to 45) regarding method of evaluation using their senses. A scale from 9 (really liked) to 1 (really disliked) was used for individual rating. The sensory assessment of the bread samples was done in the Sensory Evaluation Lab of TIMES Institute Multan. During the session, four pieces of bread from each group were given to the panelists. The members were requested to evaluate according to their perceptions and opinions.

2.10. Statistical analysis

The obtained data was statistically analyzed via Statistical Package (Costat-2003, CoHort, v 6.1.). Moreover, the analysis of variance (ANOVA) was employed to determine the level of significance through completely randomized design (CRD) as described by Montgomery (2017).

3. Results and Discussion

Adding chia flour to bakery products significantly enhanced their nutritional profile, particularly in terms . It has now been established that chia have great potential as ingredient for making healthy food items like cookies, bars, bread etc. Huerta *et al.* showed that substituting wheat flour with chia flour not only reduced saturated fat content but also increased polyunsaturated fats, particularly omega-3 fatty acids, thus

Table 3 Chemical composition (%) of bread containing defatted chia flour

Parameters	T_0	T_1	T_2	T_3
Moisture content	35.80±0.53	33.55±0.31	32.75±0.18	31.50±0.15
Crude protein	$10.85±0.08^{d}$	$12.18±0.02^{c}$	$14.75±0.06^{b}$	$16.94±0.04^{a}$
Crude fat	$2.10±0.06^{a}$	$1.82±0.03^{b}$	$1.30±0.02^{c}$	$0.50±0.05^{d}$
Crude fiber	$3.60±0.12^{d}$	$5.79±0.13^{c}$	$6.60±0.14^{b}$	$7.17±0.15^{a}$
Ash	$0.86±0.10^{d}$	$1.02±0.03^{c}$	$1.25±0.04^{b}$	$1.72±0.03^{a}$
NFE	$46.79±0.14^{a}$	$45.64±0.12^{b}$	$43.35±0.09^{c}$	$42.17±0.12^{d}$
TPC (mg GAE/g d.m.)	$1.45±0.05^{d}$	$2.70±0.23^{c}$	$3.63±0.27^{b}$	$4.20±0.13^{a}$

*T0 indicates the control group, and T1, T2, and T3 represent samples with 2%, 4%, and 6% defatted chia flour, respectively. Results are shown as mean ± SD; letters mark significant differences at 0.05 level.

enhancing the overall nutritional quality of gluten-free bread formulations.

3.1. Proximate composition and TPC of raw materials

The Table 2 provides information on the proximate composition and Total Phenolic Content (TPC) of the raw material under examination. Chia seeds demonstrated significantly higher levels of protein, fat, fibre and ash as compared to wheat flour. However, it showed lower values for moisture content and NFE. Moreover, Chia flour contains more phenolic content compared to wheat flour, contributing to its antioxidant potential. The results of current research study are in line with the findings of Adamczyk *et al.* (2021) who stated quite similar results for proximate composition of chia seeds.

3.2. Composition analysis of bread

In Table 3 chemical composition of bread made from different composite flours containing various percentages of defatted chia seeds powder is given. The moisture content across all bread samples remained relatively consistent. However, the addition of defatted chia flour significantly increased protein, crude fibre, and ash. In T_3 bread, the amount of crude fiber was doubled as compared to the control sample. The World Health Organization (WHO) recommends 30-40 grams of dietary fiber per day. The bread's nutritional value was enhanced by incorporating defatted Chia flour. The inclusion of chia seeds also contributed to better digestive health by promoting intestinal movement, lowering cholesterol, reducing triglycerides, and helping regulate blood sugar levels. Furthermore, chia's fiber content helps promote satiety, which can assist in weight management.

Chia seeds have the ability to fight against cancer and slow down the aging process. The TPC levels were significantly higher in T_2 and T_3 breads as compared toother breads. In addition, when more Chia flour without fat is added to bread, it becomes better at getting rid of harmful particles in our bodies. Coelho *et al.* (2014), found that adding chia protein hydrolysates to white bread did not change its antioxidant activity. Miranda-Ramos and Millán-Linares (2020) found that the incorporation of chia flour significantly increased the levels of proteins, lipids, and minerals in the bread, thereby enriching its nutritional value. However, Madruga *et al.* (2020) found different results. By the following results it is observed that when defatted chia flour was added to wheat bread, the overall number of antioxidants in the bread increased.

Means having different letters in a row or column indicate significant difference in results

3.3. Physical Characteristics

3.3.1. Bread Color

The results for color of the bread crumbs are displayed in Table 4. The part of the color that determines how light or dark the bread crumbs are changed from 76.70

Table 4 Color of bread containing defatted chia flour

Parameters	T_0	T_1	T_2	T_3
L*	$76.70\pm0.76_a$	$70.75\pm0.47_b$	$70.54\pm1.56_b$	$69.18\pm0.38_c$
a*	$-0.69\pm0.05_d$	$-0.53\pm0.14_c$	$-0.36\pm0.28_a$	$-0.42\pm0.43_b$
b*	$13.68\pm0.49_a$	$12.62\pm0.48_b$	$11.63\pm0.19_c$	$11.61\pm0.36_c$
ΔE	$7.79\pm0.37_a$	$6.10\pm0.24_b$	$6.40\pm0.39_b$	$6.70\pm0.45_b$

Table 5 Texture profile of bread containing defatted chia flour

Parameters	T_0	T_1	T_2	T_3
Hardness (N)	$12.95\pm0.66_a$	$12.70\pm0.43_a$	$11.10\pm0.61_b$	$11.90\pm0.50_b$
Springiness (ratio)	0.93±0.01	0.94±0.01	0.95±0.01	0.94±0.01
Cohesiveness (ratio)	0.70± 0.06	0.65± 0.04	0.70± 0.06	0.70± 0.02
Gumminess (N)	$9.02\pm0.75_a$	$8.73\pm0.37_b$	$7.83\pm0.10_c$	$7.75\pm0.15_c$
Chewiness (N × mm)	$9.02\pm0.26_a$	$7.85\pm0.70_b$	$7.40\pm0.11_b$	$7.50\pm0.12_b$

to 69.18. The other color parameters, *a*∗ and *b*∗, were between -0.69 & -0.42, and 13.68 & 11.61, respectively. The breads made with defatted chia seeds showed noticeably reduced lightness and yellowness. This suggests that the inclusion of defatted chia flour resulted in a darker and less yellow appearance than the regular bread. The color variation (ΔE) was assessed based on its value following the criteria set by the International Commission on Illumination. The color variation between the regular bread crumb and the one containing defatted chia seeds exceeded 3.5, irrespective of the quantity of defatted chia flour used. This indicates a noticeably different color compared to the standard breadcrumb. When baking bread, the temperature inside the bread is below 100 degrees Celsius, but the outside crust is above 100 degrees Celsius. Defatted Chia flour can be light cream or dark grey in color. The presence of different compounds in defatted chia flour can have an impact on the color.

Means having different letters in a row or column indicate significant difference in results

3.3.2. Bread Texture

Results for texture profile of bread made by replacing wheat flour with various percentages of defatted chia flour are presented in Table 5. The bread crumb exhibited a gumminess rating of 9.02N, even in the absence of any supplementary ingredients. The breads made with defatted Chia flour had a less sticky and

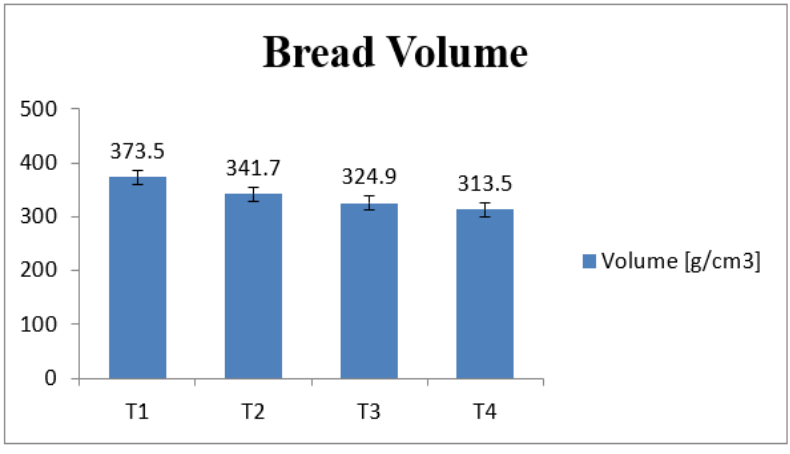

Figure 1 Volume of bread containing defatted chia flour

chewy texture compared to the control bread. Consumers don't like it when the bread crumbs are extra gummy.

According to the study by Sandri *et al.* (2017), incorporating defatted chia flour into bread made it softer and easier to break apart (with values ranging from 7.32 N×mm to 7.82 N×mm), in contrast to traditional bread, which was firmer and more difficult to chew (9.04 N×mm). Likewise, research conducted by Viswanathan (2014) indicated that adding defatted chia flour to bread makes it less fluffy and weakens the structure of the bread crumb. Furthermore, the researchers observed that incorporating defatted Chia flour had minimal influence on the bread's structural integrity or its ability to rebound.

Means having different letters in a row or column indicate significant difference in results

3.3.3. Bread Volume

Results for volume of bread made by replacing wheat flour with various percentages of defatted chia flour are presented in Figure 1. A gradual decrease in bread volume was observed with increasing chia flour substitution. It is obvious from the results that the addition of defatted chia seeds flour gradually decreased bread volume. This might be attributed to the presence of protein and fibre in the defatted chia seed flour. Previously, Sandri *et al.* (2017) discovered that chia seeds could replace gum in gluten-free bread, with higher chia flour levels (5% and 7.5%) reducing bread volume, but no significant change at 2.5%. Moreover, Parker *et al.* (2018) found similar outcomes when they partially substituted wheat flour with chia seeds in bread formulations. They found that the bread was slightly smaller (from 898 to 883 cm^3), but the difference was not big enough to be considered important.

3.3.4. Sensory Evaluation

The sensory evaluation of breads showed that they looked like well-baked bread, as depicted in Figure 2. In every situation, the bread was delicious and smelled really good. The bread became darker when defatted Chia flour was added, but it was acceptable. For T_1 samples, the color of the crumb was much

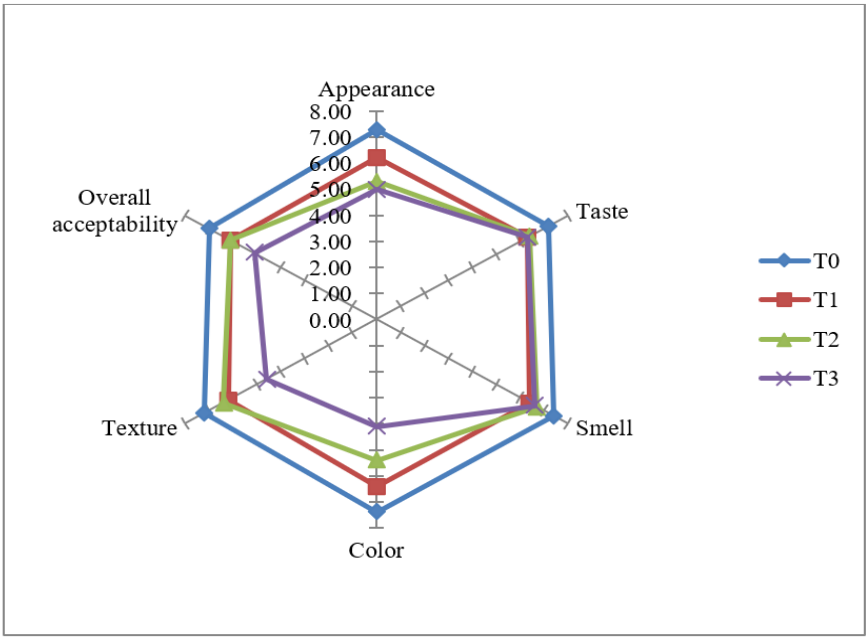

Figure 2 Sensory Evaluation of bread containing defatted chia seed flour

lighter as compared to the control bread. The markings on the bread show that control bread, T_1 and T_2 breads were dry and didn't fall apart when cut. They were also very springy. From results it is noticed that the lowest value for texture was exhibited by T_3 sample. In conclusion, the bread was given points based on how it was liked by the panelists regarding sensory attributes. Current results matched those found by Sandri *et al.* (2017) who stated similar results for the sensory properties of gluten-free bread with 15% chia flour compared to normal bread. However, the sensory assessment conducted by Kowalski *et al.* (2020) indicated that bread with up to 6% chia seed substitution did not negatively impact consumer acceptance.

4. Conclusion

The traditional dominance of wheat flour, a staple in countless kitchens worldwide, is being challenged by a growing fascination with alternative flours driven by health-conscious choices and a quest for nutritional diversity. Wheat flour, with its versatile applications in baking, pasta-making, and beyond, has long been the primary choice for many. However, using defatted Chia flour in the wheat bread recipe made the bread more nutritious. Defatted Chia flour has less fat than wheat flour, twice as much protein, around 8 times more ash, and 13 times more fiber content. This significantly increased the levels of those nutrients in the enriched bread. The higher fiber and phenolic content in chia-fortified bread contributes to potential health benefits, including improved digestive health, better cholesterol management, and enhanced antioxidant activity. Conclusively, incorporating defatted chia flour into bread can be an effective way to add these extra nutrients, making the bread more nutritious and healthy option for the people. This approach not only addresses nutritional deficiencies but also aligns with global efforts to promote healthier dietary choices.

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5.2. Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

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