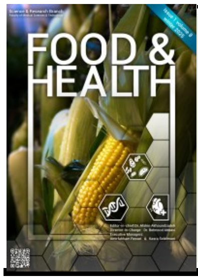

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Investigates the production of functional toast bread incorporating chia and quinoa seed sprouts and assesses their effects on the physicochemical, sensory, and antioxidant properties of the final product

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In contemporary research, significant emphasis has been placed on the development of novel functional products, largely attributable to the health benefits associated with functional foods. Among the various functional additives that have garnered interest, plant sprouts represent a particularly noteworthy area of exploration. The objective of this study was to explore the feasibility of producing functional toast bread incorporating quinoa sprout powder (QSP) and chia sprout powder (CSP). In the present study, quinoa seed powder (QSP) and chickpea seed powder (CSP) were incorporated at levels of 10%, 15%, and 20% as partial substitutes for wheat flour in the formulation of toast bread. The investigation evaluated the farinographic properties of the dough, along with various physicochemical characteristics, textural parameters, color measurements, total phenolic content, antioxidant activity, and sensory attributes of the resulting enriched breads. The findings from the farinographic analysis of the dough indicated that the bread dough supplemented with sprout powders exhibited significantly increased water absorption, extended dough development time, and a greater degree of weakening, in addition to demonstrating a reduced stability time when compared to the control sample ($p < 0.05$) The results of the bread tests demonstrated that the incorporation of corn starch powder (CSP) and quinoa starch powder (QSP), along with an increase in their respective concentrations from 10% to 20%, resulted in a significant elevation in the moisture, protein, fat, ash, and fiber content of the breads ($p < 0.05$) The incorporation of varying levels of sprout powders resulted in a significant reduction in pH, specific volume, and the L* and a* color indices, as well as in the cohesiveness and springiness of the texture of the resulting breads when compared to the control group. Conversely, an increase in the b* index was observed. Breads enriched with concentrated soluble proteins (CSP) exhibited a softer texture compared to the control sample, whereas breads supplemented with quaternary soluble proteins (QSP) demonstrated a firmer texture. A direct correlation was identified between the concentration of phenolic compounds and the antioxidant activity of the bread samples. Specifically, as the levels of Quercetin-Sodium Phosphate (QSP) and Curcumin-Sodium Phosphate (CSP) in the bread formulation increased, there was a corresponding rise in the concentration of phenolic compounds. This increase in phenolic content was associated with enhanced antioxidant activity in the breads. The findings from the sensory evaluation indicate that all bread formulations were deemed acceptable concerning their sensory attributes. Furthermore, breads supplemented exclusively with cereal straws powder (CSP) received higher sensory evaluations in comparison to those incorporated solely with quinoa straws powder (QSP) or a combination of both powders. The findings of this study suggest that the application of quinoa and sorghum flour (QSP and CSP, respectively) enables the production of functional breads characterized by elevated protein content, increased dietary fiber, and enhanced antioxidant activity.

1. Introduction

Cereal-based products hold significant importance within the food culture of numerous nations and, in general, serve as a staple food source for a substantial portion of the global population. Breads represent a significant and extensively consumed product within this category, serving as a crucial

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source of carbohydrates in the human diet. Nonetheless, breads produced from white flour exhibit a deficiency in dietary fiber, micronutrients, and macronutrients. There has been a notable escalation in consumer demand for food products that incorporate enhanced nutritional attributes, particularly in the form of functional foods (1). Functional food products play a significant role in contemporary dietary practices and contribute to overall human health. These products not only furnish essential nutrients but also exhibit substantial therapeutic effects and contribute to the prevention of nutrition-related diseases. These substances are enriched with significant bioactive compounds, including polyphenols, proteins, dietary fibers, and essential fatty acids, and are frequently classified as health-promoting foods (2).

Chia seeds (Salvia hispanica) are an ancient food source that possesses a diverse array of micronutrients, macronutrients, and bioactive compounds. These include dietary fiber, minerals, vitamins, proteins, phenolic compounds, and essential fatty acids, notably alpha-linolenic acid. Chia seeds are characterized by their gluten-free nature and possess a protein content ranging from approximately 15% to 23%. This protein content surpasses that found in various grains, including barley, wheat, oats, brown rice, and rye (3) .

Chia seeds exhibit a range of beneficial effects and biological activities, including antioxidant properties, anti-inflammatory effects, hepatoprotective capabilities, reduction of blood pressure and lipids, cardiovascular protection, and regulation of the immune system(4). Quinoa (Chenopodium quinoa Wild) is a dicotyledonous herbaceous crop belonging to the Amaranthaceae family, which is predominantly cultivated during the summer months. This species was first domesticated in the Andean regions of South America approximately 7,000 years ago (5). Quinoa seeds are characterized by their substantial protein content, which ranges from 11% to 19%. Furthermore, these seeds serve as excellent sources of a diverse array of amino acids, including but not limited to isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, histidine, cysteine, tyrosine, glycine, arginine, proline, serine, glutamine, alanine, and aspartic acid. They additionally serve as a source of carbohydrates, comprising between 49% and 68% of their composition, alongside fat content ranging from 2. 5% to 9% Furthermore, these foodstuffs are rich in essential vitamins, including thiamine, riboflavin, folic acid, and niacin. They also contain various minerals, notably iron, zinc, magnesium, and copper, with concentrations varying from 4. 8% to 24% (6). Furthermore, a diverse array of phytochemical compounds, including saponins and phenolic compounds such as ferulic acid, sinapic acid, gallic acid, kaempferol, isorhamnetin, and rutin, as well as bioactive peptides exhibiting therapeutic properties, have been identified in quinoa seeds. These findings contribute to the increasing popularity of quinoa seeds in the development of various food products (7). Quinoa's phenolic compounds serve as natural antioxidants that contribute significantly to the prevention of various health conditions, including diabetes, allergies, inflammation, and cardiovascular diseases (8). Furthermore, the saponins present in these seeds exhibit anti-inflammatory, antifungal, and immunomodulatory properties and are considered non-toxic to humans (9). Research indicates that the process of sprouting seeds enhances both their nutritional and sensory attributes. Throughout this process, macronutrients undergo breakdown, resulting in an elevation of concentrations of amino acids, simple sugars, and various other nutrients. Furthermore, the process of sprouting diminishes the concentration of anti-nutritional compounds, improves digestibility, and enhances the sensory attributes of the seeds (10). Germination is a physiological process that initiates with the uptake of water by desiccated seeds and culminates in the growth of the embryonic axis. Sprouts typically arise from the germination and subsequent growth of seeds or other vegetative storage organs, a process that occurs in the absence of light. Raw vegetables are widely consumed in Europe, Australia, the United States, and Asia, attributed to their health benefits, high nutritional value, and appealing sensory attributes (11). Sprouts contain a diverse array of nutritional compounds, including amino acids, peptides, vitamins, and minerals. Epidemiological research has indicated that the habitual consumption of sprouts is associated with a decreased incidence of various chronic diseases, including inflammatory bowel disease, certain types of cancer, arthritis, stroke, as well as cardiovascular and neurological disorders (12). The objective of the present study was to examine the impact of chia and quinoa sprout flour, both independently and in combination, on the quality characteristics and practicality of toast, with the intention of developing a functional food product.

2. Materials and Methods

2.1. Materials

The methodology delineated by Darwish et al. The methodology outlined in the study conducted in 2020, with minor modifications, was employed for the germination of chia and quinoa seeds (13). A total of 100 grams of seeds was immersed in distilled water at room temperature for a duration of two hours, maintaining a weight-to-volume ratio of 1:5. Subsequent to the washing procedure, the seeds were distributed onto trays lined with filter paper. Germination occurred over a duration of three days at a temperature of 30°C in a dark environment, with water being applied to the seeds through spraying every 12 hours. The sprouts that emerged during this period were subsequently harvested and subjected to a washing process. The sprouts were subsequently subjected to a drying process at a temperature of 50°C in an oven for a duration of 24 hours. Following this, they were ground into a fine powder utilizing an electric grinder and filtered through a 250 μm mesh sieve to ensure uniform particle size. The sprout powder generated during the study was preserved in a glass container with a tightly sealed lid and maintained in a freezer for subsequent use. The chemical composition of the sprout powder is presented in Table 1.

Table.1. Physicochemical and functional properties of wheat flour, CSP and QSP.

Samples	Wheat flour	CSP	QSP
Moisture (%)	12.40 ± 0.17 a	12.32 ± 0.07 a	12.41 ± 0.12 a
Protein (%)	11.76 ± 0.48 c	21.94 ± 0.33 a	18.08 ± 0.69 b
Fat (%)	1.16 ± 0.15 c	29.45 ± 0.32 a	6.46 ± 0.26 b
Fiber (%)	0.92 ± 0.44 c	25.26 ± 0.59 a	12.56 ± 0.81 b
Ash (%)	0.68 ± 0.02 c	4.68 ± 0.04 a	3.47 ± 0.02 b
Total phenol (mg GAE/g)	0.31 ± 0.07 c	7.41 ± 0.15 a	6.78 ± 0.12 b
Antioxidant activity (%)	26.92 ± 1.37 c	81.16 ± 0.86 a	77.84 ± 1.14 b

Values represent mean (n=3) ± SD. Different letters in each column represent statistical significant difference at 5% level. CSP: Chia sprout powder; QSP: Quinoa sprout powder.

2.2. Preparing chia and quinoa sprouts

The formulation of the control toast was established based on the weight/weight percentage of the ingredients, which comprised the following: wheat flour (100%), salt (1%), margarine (10%), dry yeast (4%), bread improver (10%), and water (50%). The preparation of the bread dough was conducted utilizing a mixer. To prepare the bread, flour, water maintained at a temperature of 20°C, and additional formulation ingredients were combined in a mixer and stirred for a duration of 10 minutes. Subsequently, the dough was allowed to rest for a duration of 10 minutes at a temperature of 35°C to facilitate the rising and fermentation processes. Subsequently, the dough, weighing approximately 500 grams, was subjected to kneading and molded into the desired shape, followed by the final fermentation process. The breads were subjected to a baking process in an electric oven maintained at a temperature of 230°C for a duration of 30 minutes (14). Chia and quinoa sprout powders were incorporated into bread formulations as partial flour substitutes, utilized independently at three different concentrations of 5%, 10%, and 15% (w/w), as well as in combination at a level of 7. 5% chia sprouts and 7. 5% The baked loaves of bread were subjected to a cooling period of two hours at ambient temperature, after which they were subsequently stored in polyethylene bags at room temperature until the time of analysis.

2.3. Preparing toast treatments

The farinographic properties of the dough, specifically water absorption, dough development time, stability time, and the degree of dough loosening after a duration of five minutes, were assessed in accordance with the AACC-approved method (21-54) (15).

2.4. Examining the Farinographic Characteristics of Dough

The moisture content of the bread was determined using the AACC Method 44-15, as specified by the American Association of Cereal Chemists (15). The protein content of the breads was quantified utilizing the methodology established by the Iranian National Standard No. [2683]. The Micro Kjeldahl method, as referenced in the standard 2683, is a widely recognized analytical technique employed for the determination of nitrogen content in organic compounds. The fat content was determined in accordance with the methodology outlined in Iranian National Standard No. A Soxhlet extraction procedure was conducted utilizing petroleum ether as the solvent, with a total extraction volume of 2862 mL. The total ash content was determined utilizing an electric furnace, in accordance with the methodology outlined by the Iranian National Standard No. Please provide the text you would like rewritten in an academic style, as "2706" does not contain any content to revise. The total fiber content was determined in accordance with the AOAC (2016) standardized method (16).

2.5. Analyzing the Chemical Composition of Bread

The specific volume of the samples was determined by calculating the ratio of the sample volume to their weight. Furthermore, the volume of the bread samples was assessed using the rapeseed replacement method (15).

2.6. Examination of the Specific Volume of Bread

In order to assess the total phenolic content and antioxidant activity of the bread samples, extracts were prepared from each specimen. A total of one gram from each sample was combined with 10 milliliters of 80% methanol and incubated with continuous stirring for a duration of 2 hours at 37°C and a rotational speed of 90 revolutions per minute. The samples were subsequently subjected to centrifugation at 4°C for a duration of 15 minutes at an acceleration of 12,000 × g. Following this process, the resultant supernatants were carefully transferred to sealed containers and stored in a freezer for later use (17).

2.7. Assessment of Total Phenolic Content in Bread

The antioxidant activity of the bread samples was assessed employing the DPPH radical scavenging method, following the protocol established by Duvan et al. Certainly Please provide the text you would like me to rewrite in an academic style, and I'll be happy to assist you. In this experiment, 2 milliliters of each extract were combined with 2 milliliters of a 0. 4 mM DPPH solution in water and incubated in the dark for a duration of 60 minutes. The absorbance of the solutions at a wavelength of 517 nm was subsequently measured utilizing a UV-Vis spectrophotometer, with gallic acid employed as the reference standard. The percentage of DPPH radical scavenging for the samples was calculated employing the subsequent equation (18).

$$\text{DPPH (\%)} = \frac{\text{Control reaction absorbance} - \text{Testing specimen absorbance}}{\text{Control reaction absorbance}} \times 100$$

2.8. Measurement of Antioxidant Activity

The coloration of the bread crust and core was assessed utilizing a Hunterlab colorimeter. The color indices L* (lightness/darkness), a* (red-green), and b* (yellow-blue) were measured, and the overall color difference (ΔE) of the breads was computed utilizing the subsequent equation (19):

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

2.9. Assess the color of the bread

In order to analyze the texture of the bread samples, a texture Analyzer equipped with a plate probe measuring 40 mm × 40 mm was employed. The testing procedure was conducted in accordance with the AACC method 74-30. Sections of the bread core, measuring approximately 2 cm by 2 cm, were extracted and subjected to compression, resulting in a reduction to 40% of the original thickness. The velocity of the upper jaw movement of the device was established at a rate of 30 mm/min. The textural parameters evaluated in this study included firmness, adhesion, chewability, and elasticity (19).

2.10. Bread Textural Profile Review

The sensory characteristics of the breads, encompassing attributes such as color, texture, flavor, odor, and overall acceptability, were assessed using a 7-point hedonic scale in conjunction with ten evaluators. The samples were sectioned into 10-gram portions, encompassing both the crust and the internal bread core. These portions were subsequently placed in white disposable plastic containers, which were randomly coded. They were then presented to the evaluators, accompanied by a sensory evaluation form. The minimum threshold for acceptable performance was established at a score of 5, which denotes an average level of quality (1).

2.11. Sensory Evaluation of Bread

The experiments were conducted in triplicate, and statistical analysis of the data was performed utilizing SPSS version 22. 0 software A completely randomized design was employed, and the analysis was carried out using Analysis of Variance (ANOVA). Duncan's multiple range test was utilized to determine significant differences among the samples at a probability level of 95%. The findings were presented as the mean accompanied by the standard deviation.

3. Results and Discussion

3.1. Bread Dough Farinography

The findings pertaining to the farinographic characteristics of toast dough, as presented in Table 2, indicate that the control sample exhibited the lowest values for water absorption, dough development time, and dough loosening degree. Notably, this control sample also demonstrated the highest level of dough stability. The incorporation of varying levels of chia and quinoa sprout powders, whether used independently or in combination, resulted in a notable increase in water absorption, dough development time, and dough loosening degree. In contrast, a significant decrease in dough stability time was observed ($p < 0.05$) The observed enhancement in water absorption of the doughs, resulting from the incorporation of chia and quinoa sprout powders, can be explained by the presence of hydrocolloids and fibers that engage in competition with flour proteins for available water (20). Chia seeds represent a notable source of mucilage, characterized by its significant capacity for water retention, with the ability to absorb up to 27 times its own weight in water (2).

Table.2. Farinograph properties of bread dough samples enriched with chia (CSP) and quinoa sprout powders (QSP).

Samples	Water absorption (%)	Dough development time (min)	Dough stability time (min)	Degree of softening after 5 min (B.U)
T0	60.13 ± 0.79 e	2.78 ± 0.33 d	7.19 ± 0.14 a	53.0 ± 2.0 d
T1	61.56 ± 0.52 d	4.10 ± 0.24 c	5.94 ± 0.17 bc	84.5 ± 1.5 bc
T2	62.10 ± 0.81 bcd	4.64 ± 0.27 b	5.97 ± 0.14 bc	92.5 ± 1.5 a
T3	62.94 ± 0.73 bc	5.47 ± 0.19 a	5.85 ± 0.10 c	90.0 ± 4.0 ab
T4	61.87 ± 0.46 cd	3.99 ± 0.28 c	6.10 ± 0.09 b	82.0 ± 3.0 c
T5	63.13 ± 0.82 b	4.52 ± 0.34 bc	6.03 ± 0.11 bc	94.0 ± 2.0 a
T6	64.80 ± 0.55 a	5.60 ± 0.21 a	6.17 ± 0.16 b	95.5 ± 3.5 a
T7	61.60 ± 0.69 cd	4.15 ± 0.17 c	5.99 ± 0.07 bc	80.5 ± 2.5 c
T8	62.44 ± 0.78 bcd	4.69 ± 0.25 b	5.89 ± 0.13 bc	97.0 ± 6.0 a
T9	63.35 ± 0.61 b	5.39 ± 0.17 a	5.95 ± 0.11 bc	95.5 ± 1.5 a

Values represent mean (n=3) ± SD. Different letters in each column represent statistical significant difference at 5% level. T0: control; T1: 10% QSP; T2: 15% QSP; T3: 20% QSP; T4: 10% CSP; T5: 15% CSP; T6: 20% CSP; T7: 5% combined powder; T8: 7.5% combined powder; T9: 10% combined powder.

Research indicates that an increase in fiber content is associated with a decrease in hydration rate and a concomitant reduction in the rate of gluten development, resulting in an extended duration for dough development (21). The observed decrease in dough stability time, coupled with the increase in the degree of dough loosening and the duration of dough development, attributable to flour substitution, can be elucidated by the dilution and weakening of the gluten network. This phenomenon occurs because gluten proteins are integral to the formation of the viscoelastic network within the dough and are essential for imparting structural strength (22). The incorporation of chia seed flour as a partial substitute for wheat flour in bread dough was found to significantly enhance various parameters, including water absorption, rising time, development time, and dough stability, while concurrently decreasing the extent of dough loosening (23). It was reported that dough incorporating sprouted barley exhibited a mixing profile comparable to that of wheat; however, it significantly influenced the extensibility properties of the dough and weakened the gluten network (24). In examining the impact of incorporating whole quinoa flour into barbaric dough on its farinographic properties, the study revealed that the addition of whole quinoa flour resulted in an increase in water absorption rate, expansion time, and the degree of dough loosening. Conversely, it was observed that the dough resistance time was significantly diminished (25). The research findings indicate that the incorporation of 10% flaxseed flour resulted in an enhancement of several parameters, specifically water absorption capacity, degree of dough loosening, dough development time, and stability time of the bread dough (26).

3.2. Chemical Composition of Bread

Moisture content plays a crucial role in determining the quality of bakery products. Research indicates that products that possess a greater capacity for moisture retention are generally of higher quality, yet they exhibit an increased tendency to become stale (27) The findings of the study examining the impact of varying levels of chia and quinoa sprout powder enrichment on the moisture content of toast, as presented in Table 3, reveal that the control sample exhibited the lowest moisture content. An observed increase in moisture content of the breads was associated with higher levels of chia and quinoa sprout powder, whether utilized individually or in combination ($p < 0.05$) The elevated moisture content observed in breads enriched with sprout powder can be attributed to the presence of hydrocolloids found in chia seeds, along with the fibrous components present in both types of seeds. These substances possess a significant capacity for water retention, thereby facilitating the retention of moisture throughout both the baking process and subsequent storage (20). Consistent with these findings, Said-Ahmed et al. In 2018, it was reported that the incorporation of chia seed flour into bread formulations led to a significant increase in the moisture content of the final product (27). In the research conducted by Pierotti et al. In the study conducted in 2020, it was observed that the incorporation of varying levels of quinoa flour resulted in an increase in the moisture content of the cakes (28).

Regarding the composition of protein, fat, and ash content (refer to Table 3), the control sample exhibited the lowest concentrations. The incorporation of increasing concentrations of chia and quinoa sprout powder, whether used individually or in combination, resulted in a statistically significant enhancement in the protein, fat, and ash content of the bread samples ($p < 0.05$) This observation was anticipated, given that chia and quinoa sprout powder exhibits higher concentrations of protein, fat, and ash components in comparison to wheat flour. As expected, the comparative analysis of the protein, fat, and ash contents in chia sprouts and quinoa sprouts indicated that breads made with chia sprout powder exhibited elevated levels of protein, fat, and ash relative to those formulated with quinoa sprout powder. The lipid composition of quinoa and chia seeds is predominantly comprised of unsaturated fatty acids. Furthermore, these seeds serve as a significant source of essential fatty acids, notably linoleic acid and alpha-linolenic acid, both of which confer various health benefits to humans (29), (30). Research indicates that quinoa and chia seeds are abundant sources of both essential and non-essential amino acids, with evidence suggesting that the concentrations of these amino acids are elevated following the germination process (31), (32). Thus, the incorporation of chia seed sprouts into bread formulations not only enhances the protein content of the products but also contributes essential amino acids that are vital for the physiological well-being of the body. The presence of elevated protein levels in chia sprouts (33). The study identified quinoa sprouts as a significant source of protein (34). Research indicates that breads supplemented with chia seed flour exhibit elevated levels of protein and fat content in comparison to control breads (27). Research indicates that an enhancement in the protein content of rice cakes occurs through the incorporation of chia seed flour (35). Research findings indicate a notable enhancement in both fat and ash content of pasta samples subsequent to the incorporation of quinoa germ flour as an enrichment component (36). Research indicates that chia seed flour is abundant in minerals, and an elevation in the proportion of this flour within the cake formulation led to a noteworthy increase in the ash content of the resultant samples (20).

Dietary fibers constitute essential components of the human diet, conferring a variety of health benefits and playing a pivotal role in the optimal functioning of the digestive system. They not only decrease blood glucose and cholesterol concentrations but also result in a reduction of low-density lipoprotein (LDL) levels (37). Table 3 presents the findings regarding the impact of varying levels of chia and quinoa sprout powder enrichment on the fiber content of toast bread. The control sample exhibited the lowest fiber content. An increase in the fiber content of the breads was observed with the incorporation of chia and quinoa sprout powder, either individually or in combination, with statistical significance ($p < 0.05$) This increase can be ascribed to the elevated fiber content present in chia and quinoa sprout powder in comparison to wheat flour. As anticipated, the fiber content of chia sprouts was comparatively greater than that of quinoa sprouts; consequently, breads formulated with chia sprout powder exhibited a higher fiber content than those made with quinoa sprout powder. In alignment with these findings, Srichawong et al. In 2017, it was observed that the fiber content of chia seed flour exceeds that of quinoa seed flour (38).

Table.3. Chemical composition of bread samples enriched with chia (CSP) and quinoa sprout powders (QSP).

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)
T0	29.76 ± 0.24 g	12.38 ± 0.25 g	1.89 ± 0.05 h	0.98 ± 0.03 g	0.94 ± 0.07 h
T1	29.93 ± 0.25 fg	13.07 ± 0.18 f	3.16 ± 0.07 g	1.60 ± 0.01 f	1.28 ± 0.08 g
T2	30.41 ± 0.31 ef	13.89 ± 0.21 d	3.53 ± 0.12 f	1.86 ± 0.04 d	1.50 ± 0.03 f
T3	30.87 ± 0.19 de	14.56 ± 0.15 c	4.29 ± 0.04 e	2.00 ± 0.01 c	1.84 ± 0.05 d
T4	31.35 ± 0.20 c	13.93 ± 0.22 d	4.61 ± 0.10 d	1.81 ± 0.03 d	1.90 ± 0.07 cd
T5	32.01 ± 0.33 b	15.10 ± 0.27 b	5.47 ± 0.09 b	2.12 ± 0.03 b	2.62 ± 0.04 b
T6	33.49 ± 0.14 a	15.87 ± 0.13 a	6.68 ± 0.05 a	2.43 ± 0.02 a	3.17 ± 0.06 a
T7	30.07 ± 0.16 fg	13.45 ± 0.10 e	4.20 ± 0.11 e	1.67 ± 0.03 e	1.63 ± 0.03 e
T8	30.65 ± 0.27 e	14.32 ± 0.16 c	4.84 ± 0.10 c	1.85 ± 0.04 d	2.02 ± 0.10 c
T9	31.10 ± 0.12 cd	15.05 ± 0.28 b	5.70 ± 0.14 b	1.98 ± 0.02 c	2.59 ± 0.08 b

Values represent mean (n=3) ± SD. Different letters in each column represent statistical significant difference at 5% level. T0: control; T1: 10% QSP; T2: 15% QSP; T3: 20% QSP; T4: 10% CSP; T5: 15% CSP; T6: 20% CSP; T7: 5% combined powder; T8: 7.5% combined powder; T9: 10% combined powder

3.3. Bread specific volume

Specific volume is a critical and influential parameter in the assessment of the quality of bakery products. Products characterized by a greater volume are regarded as possessing superior quality from the consumers' viewpoint and frequently exhibit a more desirable texture (39).

Table.4. Specific volume, total phenol content and antioxidant activity of bread samples enriched with chia (CSP) and quinoa sprout powders (QSP).

Samples	Specific volume (cm3/g)	Total phenol (mg GAE/g)	Antioxidant activity (%)
T0	2.37 ± 0.01 a	0.69 ± 0.08 g	25.42 ± 0.72 i
T1	2.30 ± 0.03 bc	1.80 ± 0.12 f	35.68 ± 0.99 h
T2	2.23 ± 0.03 d	3.06 ± 0.08 d	44.27 ± 0.63 e
T3	2.16 ± 0.01 e	4.32 ± 0.15 b	49.26 ± 0.79 bc
T4	2.35 ± 0.02 ab	2.17 ± 0.06 e	39.13 ± 0.82 f
T5	2.31 ± 0.02 bc	3.64 ± 0.10 c	47.86 ± 0.78 cd
T6	2.28 ± 0.03 cd	4.81 ± 0.14 a	52.49 ± 0.68 a
T7	2.31 ± 0.02 bc	1.94 ± 0.09 f	37.40 ± 0.51 g
T8	2.27 ± 0.04 cd	3.45 ± 0.12 c	46.15 ± 0.94 d
T9	2.23 ± 0.02 d	4.70 ± 0.03 a	50.59 ± 0.88 b

Values represent mean (n=3) ± SD. Different letters in each column represent statistical significant difference at 5% level. T0: control; T1: 10% QSP; T2: 15% QSP; T3: 20% QSP; T4: 10% CSP; T5: 15% CSP; T6: 20% CSP; T7: 5% combined powder; T8: 7.5% combined powder; T9: 10% combined powder.

The specific volume measurements for the various enriched bread treatments are delineated in Table 4. The control sample demonstrated the highest specific volume. In contrast, the introduction of varying levels of chia and quinoa sprout powder—whether applied independently or in combination—led to a reduction in the specific volume of the enriched breads when compared to the control group. Furthermore, an increase in the levels of these powders was associated with a gradual reduction in the specific volume of the resulting breads ($p<0.05$) The incorporation of gluten-free flours into the formulation of baked goods may compromise the integrity of the gluten network, resulting in a discontinuous or fibrous structural composition. This disruption is attributable to the dilution of the gluten network, which arises from a reduction in gluten protein content accompanied by elevated levels of fiber in these flour substitutes. Such changes can result in a diminished specific volume of the products produced (40). Conversely, dietary fibers engage in competition with proteins for water absorption, leading to a reduction in the water accessible to gluten. This, in turn, inhibits the formation of the gluten network (41). In the research conducted by Aksu et al. In 2019, it was observed that an increase in the proportion of quinoa flour within bread formulations resulted in a reduction in the specific volume of the resultant breads (39). A study indicated a decrease in the volume of breads formulated with fat-free chia seed flour (23). The investigation demonstrated that substituting a portion of wheat flour with flaxseed flour in the toast formulation led to a decrease in the specific volume of the resulting breads when compared to the control group (26).

3.4. Total phenolic content and antioxidant activity of bread

The total phenolic content and antioxidant activity of the breads were assessed utilizing the standard Folin-Ciocalteu method and the DPPH free radical scavenging assay, respectively. The findings are delineated in Table 4. The control sample exhibited the lowest total phenolic content, which corresponded to its reduced antioxidant activity. The incorporation of varying levels of chia and quinoa sprout powder, whether utilized independently or in conjunction, resulted in a statistically significant enhancement of the total phenolic content and antioxidant activity in the enriched breads when contrasted with the control group ($p<0.05$) The augmentation of these powders resulted in a significant increase in both the total phenolic content and antioxidant activity of the breads ($p<0.05$) The total phenolic content and antioxidant activity of breads enriched with chia sprout powder were found to be significantly higher than those enriched with quinoa sprout powder ($p<0.05$) This distinction is likely attributable to the greater concentrations of phenolic compounds present in chia sprouts in comparison to quinoa sprouts. Recent research indicates that chia seeds are rich in antioxidant compounds, particularly flavonoids and phenolic acids (2). A study has identified rosmarinic acid as the predominant component contributing to the antioxidant activity of chia seeds. Furthermore, the research indicated that chia sprouts exhibit a higher level of antioxidant activity compared to raw seeds (33).Chia seeds exhibit elevated concentrations of flavonoids, specifically in the forms of flavanones and flavones. Tocopherol (vitamin E) and carotenoids, both of which are recognized as natural antioxidants, are present in considerable quantities in chia seeds (29). Ferulic, caffeic, and p-coumaric acids are significant phenolic acids present in quinoa seeds (42). The pronounced antioxidant activity exhibited by quinoa seeds can be attributed to the presence of phenolic compounds. Antioxidants play a crucial role in neutralizing free radicals and mitigating oxidative stress (43). A study demonstrated that quinoa seed sprouts exhibit a significant level of antioxidant activity (7). A study indicated that quinoa sprouts are characterized by elevated levels of phenolic compounds, flavonoids, carotenoids (including beta-carotene and lycopene), and chlorophyll (44). The antioxidant activity of products is significantly influenced by the concentration of phenolic compounds present within them (45). The research indicated a noteworthy increase in both the total phenolic content and antioxidant activity of the bread samples as a result of incorporating higher proportions of quinoa flour (39). A study demonstrates a statistically significant enhancement in the antioxidant activity of bread concomitant with an increase in the concentration of chia flour (27).

3.5. Bread Color

The findings of the color analysis concerning toast breads supplemented with varying concentrations of chia and quinoa sprout powder are documented in Table 5.

Table.5. Color indices of bread samples enriched with chia (CSP) and quinoa sprout powders (QSP).

Samples	L*	a*	b*	ΔE
T0	65.24 ± 0.70 a	8.16 ± 0.13 a	24.53 ± 0.44 f	-
T1	63.11 ± 0.74 b	7.50 ± 0.15 b	28.01 ± 0.59 d	4.13 ± 0.25 e
T2	61.72 ± 0.55 cd	7.08 ± 0.17 cd	29.95 ± 0.25 b	6.55 ± 0.16 d
T3	60.51 ± 0.81 de	6.45 ± 0.10 e	32.20 ± 0.62 a	9.17 ± 0.19 b
T4	61.79 ± 0.72 bcd	6.98 ± 0.06 d	26.86 ± 0.51 e	4.33 ± 0.20 e
T5	59.18 ± 0.61 e	6.13 ± 0.14 f	27.73 ± 0.40 de	7.15 ± 0.28 c
T6	56.26 ± 0.67 g	5.15 ± 0.19 h	29.51 ± 0.37 bc	10.70 ± 0.21 a
T7	62.37 ± 0.46 bc	7.17 ± 0.08 c	27.55 ± 0.65 de	4.29 ± 0.13 e
T8	60.64 ± 0.82 d	6.57 ± 0.11 e	29.04 ± 0.43 c	6.63 ± 0.19 d
T9	57.88 ± 0.59 f	5.61 ± 0.15 g	31.63 ± 0.24 a	10.54 ± 0.18 a

Values represent mean (n=3) ± SD. Different letters in each column represent statistical significant difference at 5% level. T0: control; T1: 10% QSP; T2: 15% QSP; T3: 20% QSP; T4: 10% CSP; T5: 15% CSP; T6: 20% CSP; T7: 5% combined powder; T8: 7.5% combined powder; T9: 10% combined powder.

The control sample demonstrated the highest values for the L* and a* color indices, while exhibiting the lowest value for the b* color index. The integration of varying concentrations of chia and quinoa sprout powders, utilized either independently or in conjunction, led to a diminution in both brightness and redness intensity, concurrently accompanied by an elevation in the intensity of yellowness. Furthermore, a statistically significant difference in color was observed between the enriched breads and the control group ($p<0.05$) One of the primary factors contributing to the observed color change in bread samples is the chromatic properties of the additives incorporated during the formulation process. The utilization of a powder that possesses a darker pigmentation as a substitute for wheat flour results in the production of finished products exhibiting a darker coloration. Moreover, alterations in the concentrations of sugars and proteins resulting from the incorporation of sprout powder significantly impact the severity of non-enzymatic browning reactions, including the Maillard reaction. This, in turn, affects the coloration of the final product. In the research conducted by Said-Ahmad et al. In 2018, it was observed that an increase in the proportion of chia seed flour led to a reduction in both brightness and yellowness of the bread, concurrently causing a significant increase in the intensity of redness (27). A study conducted observed that the incorporation of quinoa flour resulted in an increase in redness, accompanied by a decrease in brightness and yellowness (25). A study established that pasta fortified with quinoa germ flour exhibited a decrease in the L* index and an increase in the a* and b* indices when compared to the control sample (36).

3.6. Textural properties of bread

The textural parameters of breads fortified with varying concentrations of chia and quinoa sprout powder, specifically firmness, cohesion, elasticity, and chewiness, were systematically assessed utilizing a texturometer. The findings of this analysis are delineated in Table 6. The incorporation of quinoa powder, whether used independently or in combination with other ingredients, progressively enhanced the firmness and chewiness of the breads. This phenomenon may be ascribed to the observed reduction in the specific volume of breads fortified with quinoa sprout powder. The incorporation of higher concentrations of chia sprout powder in the bread formulation resulted in a statistically significant reduction in both the firmness and chewiness of the enriched bread products ($p<0.05$) The observed decrease in firmness of the samples enriched with chia sprout powder may be attributable to the substantial quantities of mucilage contained within this powder.

Table.6. Textural parameters of bread samples enriched with chia (CSP) and quinoa sprout powders (QSP).

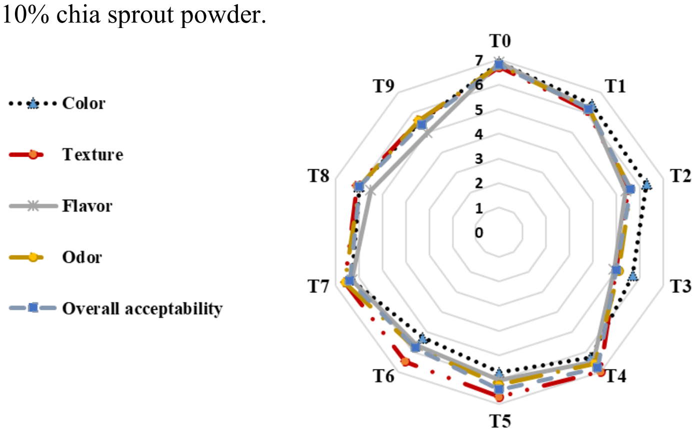
Samples	Hardness (N)	Adhesiveness	Springiness	Chewiness (N)
T0	4.14 ± 0.19 e	0.58 ± 0.01 a	0.946 ± 0.003 a	3.20 ± 0.14 e
T1	4.63 ± 0.15 c	0.44 ± 0.01 d	0.927 ± 0.006 c	3.79 ± 0.06 c
T2	5.12 ± 0.18 b	0.38 ± 0.03 f	0.909 ± 0.002 e	4.35 ± 0.17 b
T3	5.89 ± 0.10 a	0.32 ± 0.02 g	0.885 ± 0.008 f	5.16 ± 0.11 a
T4	3.54 ± 0.21 f	0.50 ± 0.03 bc	0.938 ± 0.003 b	2.48 ± 0.12 f
T5	2.96 ± 0.19 g	0.44 ± 0.02 de	0.920 ± 0.005 cd	2.02 ± 0.09 g
T6	2.27 ± 0.13 h	0.40 ± 0.02 ef	0.898 ± 0.006 f	1.59 ± 0.06 h
T7	4.20 ± 0.17 de	0.55 ± 0.02 ab	0.939 ± 0.004 ab	3.31 ± 0.13 de
T8	4.35 ± 0.14 cde	0.51 ± 0.02 bc	0.917 ± 0.003 d	3.39 ± 0.15 de
T9	4.51 ± 0.16 cd	0.46 ± 0.03 cd	0.896 ± 0.006 f	3.52 ± 0.10 d

Values represent mean (n=3) ± SD. Different letters in each column represent statistical significant difference at 5% level. T0: control; T1: 10% QSP; T2: 15% QSP; T3: 20% QSP; T4: 10% CSP; T5: 15% CSP; T6: 20% CSP; T7: 5% combined powder; T8: 7.5% combined powder; T9: 10% combined powder.

Mucilages are characterized by their notable water retention capacity, which can lead to a reduction in textural firmness by facilitating enhanced moisture retention within the product throughout both the baking and storage processes. The findings of this study demonstrate that the incorporation of chia and, in particular, quinoa sprout powder into the formulation of toast resulted in a reduction in both the cohesiveness and elasticity of the texture of the resultant bread products. In line with the results of this study, Aksu et al. (2019) reported an increase in texture firmness and a decrease in elasticity and texture cohesion of breads due to the increased level of quinoa flour (39). The researchers attributed the observed increase in texture firmness resulting from flour substitution to a reduction in specific volume. Song et al. (2020) observed that rice cakes incorporated with chia seed flour exhibited reduced cohesion and elasticity in comparison to the control sample (35).

3.7. Sensory Evaluation of Bread

The sensory attributes of samples enriched with varying concentrations of chia and quinoa sprout powder—encompassing color, texture, flavor, aroma, and overall acceptability—were evaluated employing a seven-point hedonic scale. The findings of this analysis are illustrated in Figure 1. The control sample exhibited the highest color score. In contrast, the incorporation of chia and quinoa sprout powder, whether administered individually or in combination, resulted in a significant reduction in the color score of the bread samples ($p<0.05$) The incorporation of chia sprout powder at a concentration of 10% resulted in a notable enhancement of the texture score of the bread, in comparison to the control sample. However, no statistically significant differences were detected between the samples containing 15% and 20% chia sprout powder and the control group. The inclusion of 10% combined powder did not result in a statistically significant difference in texture scores when compared to the control group. However, an increase in the proportion of combined powder, as well as the use of quinoa sprout powder independently, was associated with a notable reduction in the texture scores of the breads produced, relative to the control. With regard to the sensory characteristics of taste and smell, the control sample received the highest rating; however, there was no statistically significant difference observed between this sample and the bread incorporating 10% chia sprout powder.



T0: control; T1: 10% QSP; T2: 15% QSP; T3: 20% QSP; T4: 10% CSP; T5: 15% CSP; T6: 20% CSP; T7: 5% combined powder; T8: 7.5% combined powder; T9: 10% combined powder.

Figure.1. Sensory properties of bread samples enriched with chia (CSP) and quinoa sprout powders (QSP).

As the concentrations of chia and quinoa sprout powder were elevated, either individually or in combination, a gradual decline in the sensory attributes of taste and aroma was documented in the breads. The most pronounced reduction in these scores was attributable to the inclusion of quinoa sprout powder. In terms of overall acceptance, the control sample and the breads incorporating 10% and 15% chia sprout powder, as well as the formulation with 10% of the combined powder, received the highest scores. Notably, there was no statistically significant difference observed among these three samples. As the concentrations of chia and quinoa sprout powder increased, whether individually or in combination, the overall acceptance score of the breads exhibited a gradual decline. Notably, the most significant decrease was observed in relation to quinoa sprout powder. The overall acceptance scores of the enriched bread samples varied from 5. 00 to 680, suggesting that, broadly speaking, all treatments evaluated in this study were deemed acceptable with respect to their sensory attributes. Notably, the treatments incorporating chia sprout powder exhibited elevated levels of sensory acceptance. A recent study indicated that although the substitution of wheat flour with quinoa flour at levels of 10% or higher resulted in a decline in taste, texture, and overall acceptance scores of the bread samples, all formulations remained well-received by participants (39). The study demonstrated that breads formulated with varying concentrations of chia flour displayed enhanced sensory characteristics in comparison to the control sample (27).

4. Conclusion

The findings of this study indicate that higher concentrations of chia and quinoa sprout powder are associated with an enhancement in water absorption of bread dough. Additionally, there was a significant improvement in the nutritional composition of the bread, encompassing the levels of protein, fat, fiber, and ash content. The specific volume of enriched breads was found to be significantly lower than that of the control sample. The incorporation of elevated levels of chia and quinoa sprout powder in the bread formulation resulted in a marked enhancement in both the concentration of phenolic compounds and the antioxidant activity of the resultant bread products. The texture of breads enriched with quinoa sprouts exhibited a firmer consistency, whereas the texture of breads incorporating chia sprouts demonstrated a softer profile in comparison to the control sample. The enrichment of toast bread with elevated levels of quinoa and chia sprout powder resulted in a noticeable decline in sensory attributes, including taste, aroma, color, and overall acceptability, when compared to the control sample. Notwithstanding, the treatments investigated in this study demonstrated acceptable sensory characteristics. Notably, the highest levels of sensory acceptance were associated with the treatments supplemented with chia sprout powder. In summary, the findings of this study indicate that chia and quinoa sprout powders serve as exceptional sources of protein, beneficial lipids, dietary fiber, and antioxidant compounds. Consequently, these powders may be regarded as functional additives. The findings of this study indicate that quinoa sprout powder, and particularly chia, can be effectively utilized in the production of functional toast. The findings indicate that a concentration of 20% chia sprout powder may be identified as the optimal treatment.

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