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Impact of Saline Water on Nutritional Quality of Sprouted Quinoa, Chickpea and Faba Bean as Wheat Alternatives

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Abstract: This study was conducted from 2019 to 2024 to investigate the effect of salinity on sprout growth, as well as the chemical composition and mineral content of three-grain crops: quinoa, chickpea, and faba bean. A proximate analysis was conducted to compare flour derived from these sprouted seeds with commercial wheat flour. Additionally, it assessed how different mixtures of sprouted flour influence the chemical, physical, and sensory properties of gluten-free cakes. Notably, chickpea seeds and their sprouted flour exhibited high protein content, ranging from 21.8 to 22.5 g/100g, while faba bean seed flour and sprouts showed even higher protein levels (26.70 to 27.34 g/100g). The protein content of sprouted crops surpassed that of commercial wheat flour. Sensory evaluations indicated no significant differences among the various gluten-free sprouted flour mixtures. Accordingly, this study recommends sprouting as a viable method to enhance nutritional value and create more diverse diets, especially for individuals with celiac disease.

1 Introduction

Sprouts are the food and medicine of the future. Specialists in healthy nutrition have become interested in determining the biological value of nutritious sprouts (Peñas et al 2008, Marton et al 2010).

Researchers worldwide are increasingly interested in identifying gluten-free items suitable for inclusion in patients' diets, due to the growing number of individuals with celiac disease. This is because a gluten-free diet is currently the only treatment available for this condition. Gluten consumption triggers the immune-mediated systemic disorder known as celiac disease, or gluten intolerance (Husby et al 2020). Celiac disease arises from gluten intake, resulting in inflammation and mucosal damage in the small intestine, which leads to the loss of essential nutritional elements, such as iron, folic acid, calcium, and fat-soluble vitamins. Strict adherence to a gluten-free diet is the only available treatment (Ludvigsson and Green 2011).

Given that lupine beans (*Lupineus albus*) have high amounts of protein (36–52 g/100 g), fiber (30–40 g/100 g) and vitamins (thiamine, riboflavin, niacin, folate, also and vitamin E), they can be used as the foundation for gluten-free cookies (Maghaydah et al 2013). Sprouting is soaking, draining, and waiting for seeds to germinate. It is a low-cost and efficient technique for raising the nutritional content of grain legumes and cereals (Khattak et al 2007).

Shaban et al (2023) found that the levels of protein, fat, carbohydrates, crude fiber, ash, and moisture were lower in the sample containing 100% wheat flour (72% extraction) compared to those in substituted samples with sprouted whole wheat grain flour and dull sprouted faba bean flour. Therefore, this work aims to utilize legumes and grains as alternatives to wheat for producing gluten-free bakery products of high nutritional quality. The effects of saline water on sprout growth, as well as the chemical composition and mineral content of the three-grain crops—quinoa, chickpea, and faba bean—have also been evaluated.

2 Materials and Methods

This study was conducted in the Horticulture Department at the Faculty of Agriculture, Ain Shams University, the Regional Center for Food and Feed (RCFF), and the Gluten-Free Products Laboratory at the Agricultural Research Center (ARC) in Giza, Egypt, from 2019 to 2024. Faba beans, chickpeas, and quinoa seeds were sourced from the Agricultural Research Center and the Crops Research Institute in Giza, Egypt. The Cairo Milling Company supplied the 72% extraction of local baking flour. Ground sprouts were utilized instead of wheat flour to prepare cakes.

2.1 Preparation of sprouted quinoa, faba bean and chickpea flour

Quinoa grains, faba bean, and chickpea seeds were cleaned to remove broken, damaged, and off-color grains. Seeds were then sprouted using the glass jar method, as previously reported by Abdallah (2008). Sprouted grains were soaked in a NaCl solution (2000 ppm). During a day of sprouting, samples were extracted to measure the percentage of germinated sprouts, length of radicals, and fresh and dry sprout weights (mg).

Following the day of sprouting in jars, the sprouts were collected, sun-dried, and ground to make sieved grain flour (Dzowela et al 1995). For chemical analysis, samples were further dried at 60°C in an incubator for 48 hours. The remaining dried flour was reserved for cake decorating and chemical analysis.

2.2 Preparation of composite flour for cake samples

The cake is made using wheat flour (72% extraction) as control and sprouted grain flour germinated in normal tap water or NaCl saline solution as follows:

100% market wheat flour (Control)
50% salted chickpea sprouts (SCS) + 50% salted faba bean sprouts (SFS).
50% salted faba bean sprouts (SFS) + 40% salted chickpea sprouts (SCS) + 10% salted quinoa sprouts (SQS).
50% normal chickpea sprouts (NCS) + 50% normal faba bean sprouts (NFS).
50% normal faba bean sprouts (NFS) + 40% normal chickpea sprouts (NCS) + 10% normal quinoa sprouts (NQS).

2.3 Cakes formula and ingredients

A cake recipe was prepared as described by Adebowale et al. (2012) with some modifications: a simple mixture for making the cake dough consisted of 150 g of sugar, 500 g of fat, and 100 g of fresh milk or water. The mixture was stirred for one minute at 125 rpm to form a homogeneous blend, and then 1000 g of mixed flour, 16 g of baking powder, and 5 g of vanilla were added in that order. The mixture was combined for three minutes at 60 rpm. The cake mix was then formed using a piping bag fitted with a specific tip and baked at 180°C for 30 minutes on a tray in an oven.

2.4 Chemical composition investigation

2.4.1 Proximate analysis

The contents of water, ash, total protein, lipids, and crude fiber in the samples were determined according to the AOAC (2012) method, while total carbohydrate was calculated by subtraction. The energy value was computed using the Atwater factor method [(9 x fat) + (4 x carbohydrate) + (4 x protein)], as described by Osborne and Voogt (1978), Chinma and Igyor (2007), and Nwabueze (2007).

2.4.2 Sensory analysis

Sensory evaluation of cakes was conducted by 10 panelists according to the method of Johnson et al (1989). The characteristics of cakes including odor, texture, taste and color were recorded. Cake samples were evaluated after 24 h of preparation by trained judges using a 9-point Hedonic score system with 1 = extremely dislike, 2 = dislike very much, 3 = moderately dislike, 4 = slightly dislike, 5 = neither liked nor dislike, 6 = slightly liked, 7 = moderately liked, 8 = liked very much and 9 = extremely liked. Scores were collected and analyzed statistically.

2.5 Statistical analysis

The data were subjected to analysis of variance using a completely randomized design and the least significant difference (LSD) at the 0.05 level according to the method described by Snedecor and Cochran (1980).

3 Results and Discussion

3.1 Effect of salinity on the sprout development and chemical profile

Regarding quinoa sprouts, data in **Table 1** illustrate that treating quinoa seeds with sodium chloride (2000 ppm) increased germination (%) compared to the control treatment. On the other hand, the radical length and 10-sprout fresh weights were reduced compared to those of the control; however, the 10-sprout dry weights were unaffected.

Concerning faba bean, data in **Table 1** show that treating faba bean seeds with NaCl (2000 ppm) reduced germination (%), radical length and 10-sprout fresh weight significantly compared with those of control while 10-day sprout dry weights were not significantly affected.

Finally, data in **Table 1** shows that treating chickpea seeds with NaCl (2000 ppm) reduced germinated sprout (%) and radical length significantly compared with those of control while 10-sprout fresh and dry weights were not significantly affected.

3.2 Impact of sprouting using saline water on the proximate analysis of sprout flours

Table 2a illustrates the effect of sprouting using saline water on the proximate analysis of quinoa flour. Regarding moisture, carbohydrates, and energy, data showed that quinoa grains had lower moisture compared with those of the control but higher protein, total lipid, fiber and ash contents.

Using normal sprouting quinoa flour increased moisture, carbohydrates and fiber compared with those of quinoa grains. On the contrary, using normal sprouting quinoa flower reduced protein, total lipid, ash and energy compared with quinoa grain results.

Using salted quinoa sprouting flour significantly increased protein, total liquid, ash, and energy compared with using normal quinoa sprouting flour. On the contrary, it significantly reduced moisture, carbohydrates, and fiber.

Regarding the faba bean, **Table 2b** illustrates the effects of sprouting with saline water on the proximate analysis of regular faba bean flour. The data show that faba bean seeds had higher protein, total lipid, ash, and energy compared to those of the control, but they exhibited significantly reduced moisture, carbohydrates, and fiber. On the other hand, the data indicate that using normal faba bean flour resulted in increased protein, total lipid, ash, and energy, alongside significantly reduced moisture, carbohydrates, and fiber when compared to faba seeds.

On the other hand, data also shows that using salted faba flour significantly increased carbohydrates and energy and reduced protein, fiber and ash. There were no significant effects on moisture and total lipids compared with those of normal sprouted faba bean flour.

Regarding the chickpeas, **Table 2c** illustrates the effect of sprouting with saline water on the proximate analysis of normal chickpea flour. The data revealed that chickpeas contained higher levels of protein, total lipids, fiber, ash, and energy, but lower moisture and carbohydrates. Conversely, using normal chickpea flour increased protein, total lipids, and ash while significantly reducing moisture, carbohydrates, fiber, and energy. The use of salted chickpea flour led to increases in protein, carbohydrates, fiber, and energy, while significantly decreasing moisture, total lipids, and ash compared to normal chickpea sprout flour.

Sanni et al (2006) demonstrated that lower humidity provides higher product quality in the market.

This observation aligns with other scientific findings indicating that sprouting enhances the nutritional quality of food products, especially regarding protein content (Enujiugha et al 2003, Abdallah 2008, Sade 2009, Steve 2012). The highest levels of crude protein are found in seed sprouts, attributed to the activation of various enzymes during germination and the formation of specific non-protein nitrogen molecules, including nucleic acids. As a result, this may lead to increased protein levels (Traoré et al 2004, Moongngarm and Saetung 2010).

3.3 Effect of different sprouting flour mixes and saline water on free-gluten cake quality

Table 3 demonstrates the effect of using different salting sprouting flour mixtures on the proximate composition of free-gluten cake quality. The data showed that using different mixes of sprouting flour for making free-gluten cakes significantly increased moisture, protein, ash, and fiber, but reduced carbohydrates, lipids, and energy compared to the control. Data illustrates that using a normal sprouting mix for making cakes reduced fiber significantly compared with the control.

Table 1. Effect of NaCl concentrations in sprouting solution on one-day-old quinoa, faba bean and chickpea sprout characters

Characters Salinity (ppm)	Germinated sprouts percentage (%)	Radical length (mm)	10 Sprouts fresh weight (mg)	10 Sprouts dry weight (mg)
quinoa sprouts				
Tap water	98.11^{b}	7.66^{a}	0.0496^{a}	0.033^{a}
NaCl 2000PPM	98.55^{a}	4.55^{b}	0.0413^{b}	0.031^{a}
L.S.D (0.05)	0.044	0.622	0.005	N. S
faba bean sprouts				
Tap water	97.11^{a}	6.55^{a}	18.06^{a}	7.49^{a}
NaCl 2000PPM	68.11^{b}	4.55^{b}	16.92^{b}	7.28^{a}
L.S.D (0.05)	0.872	0.695	1.064	N. S
chickpea sprouts				
Tap water	97.89^{a}	5.89^{a}	12.85^{a}	5.76^{a}
NaCl 2000PPM	63^{b}	3.44^{b}	13.1^{a}	5.8^{a}
L.S.D (0.05)	**2.224**	**0.687**	**N. S**	**N. S**

N.S = not significant

Table 2a. Effect of sprouting using saline water on the proximate analysis of quinoa flour (g/100g)

Nutrient (%)	Moisture	Protein	Carbohydrates	Total lipid	Fiber	Ash	Energy kcal
(control)	11.69^{a}	11.10^{d}	71.98^{a}	1.65^{d}	2.06^{d}	1.54^{d}	347.02^{a}
Quinoa grains	10.50^{c}	15.68^{a}	60.20^{d}	4.43^{a}	2.49^{c}	6.70^{b}	343.36^{c}
(NQS)	10.85^{b}	13.40^{c}	62.56^{b}	3.90^{c}	2.89^{a}	6.40^{c}	338.96^{d}
(SQS)	9.39^{d}	14.28^{b}	62.38^{c}	4.15^{b}	2.69^{b}	7.12^{a}	343.93^{b}
L.S.D (0.05)	**0.029**	**0.021**	**0.022**	**0.011**	**0.032**	**0.019**	**0.175**

(Control) 100% market wheat flour, (SQS) salted quinoa sprouts and (NQS) normal quinoa sprouts. Different letters in the same column indicate insignificant differences at a significant level of $p<0.05$.

Table 2b. Effect of sprouting using saline water on the proximate analysis of faba bean flour (g/100g)

Nutrient (%)	Moisture	Protein	Carbohydrates	Total lipid	Fiber	Ash	Energy kcal
(control)	11.69^{a}	11.10^{d}	71.98^{a}	1.65^{c}	2.06^{b}	1.54^{d}	347.02^{c}
Faba bean seeds	10.21^{b}	22.44^{c}	58.56^{b}	2.21^{b}	2.34^{a}	4.24^{c}	343.89^{d}
(NFS)	7.58^{c}	27.34^{a}	55.48^{d}	2.31^{a}	0.82^{c}	6.47^{a}	352.07^{b}
(SFS)	7.60^{c}	26.70^{b}	57.70^{c}	2.30^{a}	0.77^{d}	4.93^{b}	358.30^{a}
L.S.D (0.05)	**0.022**	**0.019**	**0.014**	**0.022**	**0.017**	**0.022**	**0.279**

(Control) 100% market wheat flour, (SFS) salted faba bean sprouts, (NFS) normal faba bean sprouts. Different letters in the same column indicate insignificant differences at a significant level of $p<0.05$.

Table 2c. Effect of sprouting using saline water on the proximate analysis of chickpea flour (g/100g)

Nutrient (%)	Moisture	Protein	Carbohydrates	Total lipid	Fiber	Ash	Energy kcal
(control)	11.69^{a}	11.10^{d}	71.98^{a}	1.65^{d}	2.06^{d}	1.54^{d}	347.02^{d}
Chickpea seeds	5.2^{b}	18.26^{c}	62.80^{b}	5.76^{b}	2.48^{a}	3.51^{c}	376.07^{b}
(NCS)	3.6^{c}	21.48^{b}	57.53^{d}	6.46^{a}	2.15^{c}	4.86^{a}	374.21^{c}
(SCS)	2.3^{d}	21.84^{a}	60.51^{c}	5.46^{c}	2.40^{b}	4.75^{b}	378.52^{a}
L.S.D (0.05)	**0.020**	**0.025**	**0.016**	**0.015**	**0.020**	**0.022**	**0.258**

(Control) 100% market wheat flour, (SCS) salted chickpea sprouts and (NCS) normal chickpea sprouts. Different letters in the same column indicate insignificant differences at a significant level of $p<0.05$.

Table 3. Effect of different mixes of sprouting flour using saline water on proximate composition of free-gluten cakes quality (g/100g)

Nutrient (%)	Protein	Ash	Moisture	Lipids	Fiber	Carbohydrates	Energy kcal.
(Control)market wheat flour	8.6[e]	8.33[c]	7.13[e]	31.5[a]	3.9[c]	40.54[a]	480.08[a]
50%(NCS)+50%(NFS)	17.2[a]	8.64[a]	13.2[a]	24.70[b]	2.31[d]	34.07[e]	427.33[b]
50%(SCS) + 50%(SFS)	16.8[b]	8.73[a]	10.81[d]	21.38[e]	4.15[b]	38.14[c]	412.18[e]
50%(NFS)+40%(NCS)+10%(NQS)	16.02[c]	8.45[bc]	11.9[c]	22.41[d]	2.3[d]	38.94[b]	421.55[c]
50%(SFS)+40%(SCS)+10%(SQS)	15.3[d]	8.59[ab]	12[b]	23.71[c]	4.43[a]	35.96[d]	418.40[d]
L.S.D (0.05)	**0.023**	**0.141**	**0.042**	**0.019**	**0.019**	**0.028**	**0.094**

(SCS) salted chickpea sprouts (SFS), salted faba bean sprouts (SQS), salted quinoa sprouts (NCS), normal chickpea sprouts (NFS), normal faba bean sprouts (NQS), normal quinoa sprouts. Different letters in the same column indicate insignificant differences at a significant level of $p<0.05$.

Data also showed that using saline sprouting mix flour (faba bean and chickpeas) to make cakes increased fiber and carbohydrates but significantly reduced proteins, moisture, lipids and energy in the cakes produced, while ash content was not significantly affected.

Adding 10% saline quinoa sprouting flower to the faba bean and chickpea mix increased moisture, lipids, fiber and energy but significantly reduced protein and carbohydrates in the resulting cakes compared to the same blend using regular sprout flour.

A cake sample made from 50% faba bean flour and 50% chickpea flour was used to determine the minimum moisture content (10.81%) of the cakes. It was noted that cakes with lower moisture content, if stored appropriately in a hygienic environment with suitable packaging materials, could have an extended shelf life (El Drazy et al 2024).

The present study demonstrates that when quinoa, faba beans, and chickpeas are germinated in 2000 ppm NaCl, the moisture content of the cake samples is lower than that of regular wheat flour. Cakes made with salted faba bean and chickpea sprouts (50% + 50%) exhibited the highest protein content (17.2 g/100g), the lowest carbohydrate content (34.04 g/100g), and the highest energy content (427.35 kcal/100g). In contrast, cakes made with market wheat flour contained the least amount of protein (8.6 g/100 g) compared to those made with a mixture of chickpea sprouts and faba bean in salt water (17.2 g/100 g). This may be attributed to the use of chickpea and faba bean seed flour, both of which are high in crude fiber content (Shaaban et al 2023).

4. Effect of different sprout mixes on sensory evaluation of free-gluten cakes

Regarding the sensory evaluation of gluten-free cakes made from various blends of sprouted flour compared to regular flour, the data in Table 4 indicate that different mixes significantly diminished the taste, odor, color, and texture compared to regular flour. However, utilizing a saline mix (faba beans and chickpeas) or adding 10% quinoa to all mixes did not significantly impact the sensory attributes.

Maiti et al. (2006) stated that incorporating faba bean, chickpea, and quinoa into gluten-free products represents a significant opportunity to provide more options for individuals requiring a gluten-free diet while also offering these ingredients unique flavors, textures, and nutritional benefits. Additionally, their inherent qualities may enhance overall health and well-being in individuals with gluten sensitivity. The effect of saline water sprouting on the sensory assessment of gluten-free cakes varied in terms of flavors, textures, colors, and aromas. A 10-point taste scale was applied to the cake samples. After a 24-hour preparation period, the judges were informed and scored the cakes on a scale from 1 (strong dislike) to 1 (strong like). The scores were summed and statistically evaluated based on the results. Cakes made with a 50% chickpea and faba bean sprout mixture performed better at 2,000 ppm NaCl. The panel test score (6.5), color score (7.05), and texture score (7) of the market flour cakes (8.7) were the top three scores.

Table 4. Effect of different mixes of sprouting flour on sensory evaluation of free-gluten cakes

Sensory characters	Taste	Odor	Color	Texture
(Control) market wheat flour	8.7^a	8.8^a	8.8^a	8.7^a
50%(NCS)+50% (NFS)	6.5^b	7.05^b	7.3^b	7^b
50% (SCS) + 50% (SFS).	6^b	7.3^b	7.3^b	7^b
50%(NFS)+40%(NCS)+10%(NQS)	5.5^b	6.4^b	7^b	6^b
50%(SFS)+40%(SCS)+10%(SQS)	6.15^b	6.75^b	7.15^b	6.1^b
L.S.D (0.05)	**1.058**	**1.208**	**1.301**	**1.440**

(SCS) salted chickpea sprouts (SFS), salted faba bean sprouts (SQS), salted quinoa sprouts (NCS), normal chickpea sprouts (NFS), normal faba bean sprouts (NQS), normal quinoa sprouts. Different letters in the same column indicate insignificant differences at a significant level of $p<0.05$.

4 Conclusions

In conclusion, the integration of faba beans, chickpeas, and quinoa in gluten-free products has offered a variety of delicious and nutritious alternatives. By understanding the various properties and benefits of these plant-based ingredients, individuals following a gluten-free diet can enjoy a wide and satisfying culinary experience. As the demand for gluten-free products continues to rise, exploring innovative approaches that enhance both taste and health is essential.

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