

## Research Article

# Technological, Sensory, and Hypoglycemic Effects of Quinoa Flour Incorporation into Biscuits

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**Background.** Biscuits are consumed by all of society in the world. Incorporation of different ratios of quinoa flour into wheat flour for the production of biscuits is needed for the production of functional foods. **Objective.** This study aimed to evaluate the incorporation of 12.5% or 25% quinoa flour into biscuit production, evaluate rheological and sensory characteristics, and investigate the effect of the consumption of 20% cooked biscuits on diabetic rats. **Design.** The gross chemical composition, total carotenoids, phenolic and flavonoids of wheat flour and quinoa flour, and the rheological properties of the control, 12.5% quinoa, and 25% quinoa biscuit dough were determined. The effects of consumption of 12.5% quinoa and 25% quinoa biscuits on diabetic rats were investigated. **Results.** Quinoa flour had significantly higher levels of the gross chemical composition except for carbohydrate and increased phenolic compound and flavonoids content than those in wheat flour. Increasing the amount of quinoa flour in the biscuits could increase the farinograph and extensograph values of the dough. Biological results showed that the highest improvement in nutritional values appeared in the diabetic rat group, which consumed 25% quinoa biscuit for 60 days. The consumption of 12.5% quinoa biscuit and 25% quinoa biscuit showed a decline in blood glycosylated hemoglobin and glucose and an elevation in insulin levels compared with the positive control diabetic rat group. **Discussion and Conclusion.** It is encouraging to replace wheat flour with quinoa flour in biscuit manufacturing owing to positive effects on both the technological properties and sensory evaluation of biscuits. The increase of quinoa flour up to 25% had favorable nutritional values and hypoglycemic effects.

## 1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a member of the Chenopodiaceae family and acts as pseudocereal due to yield grains and consumed as cereals or flour products [1, 2]. Quinoa has high nutritional value and acts as a complete food. It offers all essential amino acids, such as methionine, histidine, and lysine; essential fatty acids, such as oleic and linoleic acids; and dietary fiber, which detoxify the waste products and toxins. It also has a wide range of minerals and vitamins, more than those present in cereals and legumes [3–7].

Quinoa has been cultivated worldwide as a new crop species directed at technological and commercial

importance. It is used in cooking, baking, modified food products such as breakfast cereals, pasta, and cookies, industrial use of starch, protein, and saponin, and the pharmaceutical industry and animal feeding [1, 8–10].

Currently, quinoa is incorporated into wheat flour at a definite percentage for bakery production as cakes, bread, and biscuits to enrich the sensory characteristics of the baked goods, such as the aroma, taste, texture, and acceptability, in addition to increasing the nutritious and health benefits of baked products [11–13]. Quinoa is known as a functional food because it improves lipid parameters, triglycerides, and the glycemic index in addition to its beneficial components, such as vitamins and minerals, and is gluten free [7, 14].

Biscuits are consumed by nearly all of society because of their low cost, availability, taste variation, and relatively long shelf life in addition to their good nutritional quality, which leads to the importance of increasing their protein, vitamin, and fiber content. It has been of interest to improve the nutritional and sensory quality of biscuits by incorporating functional foods, such as those in gluten-free biscuits. A 60% substitution of wheat flour with quinoa flour resulted in dark-colored cookies with increased hardness and decreased volume and chewiness, so the addition of quinoa flour should be not more than 50% to enhance nutritional and sensory properties [15–19].

Therefore, this study aimed to determine the incorporation of different ratios of quinoa flour into wheat flour for the production of biscuits, to evaluate the rheological and sensory characteristics, and investigate the effect of the consumption of 20% biscuits on diabetic rats.

## 2. Materials and Methods

Wheat flour, quinoa flour, sugar, salt, eggs, margarine, lecithin, baking powder, and vanillin were purchased from local markets. Twenty-eight albino rats weighing  $120 \pm 7$  g were provided by the experimental animals' center in the Research Center in Prince Sultan Military Medical City, Riyadh. Ethical guidelines for investigations involving experimental animals were followed throughout the study. The experiments were carried out with the help of the staff of the Scientific Research Center of the MSD at their experimental animal (REC AP2411/16A). The basal diet was formed [20].

The gross chemical composition of wheat flour and quinoa flour, including protein, lipids, fiber, ash, and moisture, was estimated according to AACC methods [21]. The carbohydrate content (%) of wheat flour and quinoa flour was calculated.

The total phenolic compound content of wheat flour and quinoa flour was determined calorimetrically and expressed as gallic acid equivalents (gGAE/1000 g) [22]. The total carotenoid and flavonoid contents were determined spectrophotometrically according to standard methods [23]. The water-holding capacity and oil-holding capacity of wheat flour and quinoa flour were determined [24, 25].

The ingredients of different biscuit batters illustrated in Table 1 were mixed, rested for half an hour, laminated, shaped, and then, baked at  $220^{\circ}\text{C}$  for 15 min to prepare control, 12.5% quinoa representing 6.22% of dry ingredients of biscuit, and 25% quinoa biscuits representing 12.44% of dry ingredients of biscuit [26].

The rheological properties of the control, 12.5% quinoa, and 25% quinoa biscuit dough were determined by using Brabender farinograph and extensograph instruments according to the AACC method [21]. Sensory evaluation of the control, 12.5% quinoa, and 25% quinoa biscuits was conducted for appearance, texture, color, taste, odor, and overall acceptability by ten trained sensory panelists using a hedonic scale.

To investigate the antidiabetic effect, rats fed a basal diet and water *ad libitum* were allowed to adapt for one week. Rats were injected intraperitoneally with streptozotocin at a

dose of 50 mg/kg body weight in 0.1 M citrate buffer to induce diabetes, which was confirmed by the elevation of blood glucose samples on the third day. Rats were randomly divided into four groups as follows:

The positive control rat group consumed a basal diet.

The control biscuit rat group consumed the basal diet containing 20% dried, powdered control biscuit.

The 12.5% quinoa biscuit rat group consumed the basal diet containing 20% dried, powdered 12.5% quinoa biscuit.

The 25% quinoa biscuit rat group consumed the basal diet containing 20% dried, powdered 25% quinoa biscuit.

Daily food intake and weekly body weight were recorded. The feed efficiency ratio (FER) was calculated.

Rats were sacrificed after 60 days to estimate hemoglobin, glycosylated hemoglobin, glucose, and insulin [27]. The obtained results of triplicate assays were statistically analyzed by analysis of variance (ANOVA), and significant differences among Duncan's multiple tests were determined using SPSS computer software.

## 3. Results and Discussion

The analysis of the wheat flour and quinoa flour samples used in the production of the control, 12.5% quinoa, and 25% quinoa biscuits is presented in Table 2. The wheat flour had significantly lower protein, lipids, fiber, ash, and energy levels than quinoa flour. On the other hand, wheat flour had higher contents of carbohydrate and moisture than quinoa flour. The results were in agreement with the results of many authors [5, 11, 28, 29]. In contrast, quinoa flour had 58.3% carbohydrate, 13.5% crude protein, 9.5% crude fiber, 1.2% total ash, and 11.2% moisture. Also, 12% protein, 6.5% lipid, 77% carbohydrate, and 3% mineral contents in quinoa grain were estimated [30]. The variation in the chemical composition of quinoa flour was related to the area of cultivation and germination period [17].

Table 3 shows that higher total carotenoid, phenolic, and flavonoid contents were observed in quinoa flour than in wheat flour. These values were consistent with many authors who reported that quinoa has significant amounts of antioxidant compounds such as carotenoids, polyphenols, and phenolic acids [4, 25, 31]. Quinoa has kaempferol, ferulic, gallic acids, isorhamnetin, and routine bioactive components [4, 32]. Polyphenols, phytosterols, isoflavones, and flavonoids have excellent antioxidant properties and contribute nutraceutical benefits. The quinoa flavonoid level was higher than that of blueberries, reaching levels similar to those of flavonoid-rich fruits [33, 34]. The variations in mineral, saponin, and total phenolic compound contents in quinoa are mainly due to methods of processing and cooking [35].

Table 4 shows that the differences between the water-holding capacity and oil-holding capacity of wheat flour and quinoa flour showed a significant difference. Wheat flour had significantly higher water- and oil-holding capacity

TABLE 1: Ingredients in control, 12.5% quinoa, and 25% quinoa biscuits.

	Wheat flour (g)	Quinoa flour (g)	Margarine (g)	Sugar (g)	Egg (g)	Lecithin (g)	Vanillin (g)	Salts (g)	Baking powder (g)	Water (g)
Control biscuit	200	—	32	60	100	1.2	0.5	1	7.2	30
12.5% quinoa biscuit	175	25	32	60	100	1.2	0.5	1	7.2	30
25% quinoa biscuit	150	50	32	60	100	1.2	0.5	1	7.2	30

TABLE 2: Chemical composition of wheat flour and quinoa flour.

Nutrient flour	Protein (g/100 g)	Lipids (g/100 g)	Fiber (g/100 g)	Ash (g/100 g)	Carbohydrate (g/100 g)	Moisture (g/100 g)	Energy (kcal/100 g)
Wheat	10.99 ± 0.95b	1.45 ± 0.08b	1.75 ± 0.06b	1.69 ± 0.07b	76.13 ± 3.61a	7.99 ± 0.88b	361.53 ± 4.66b
Quinoa	15.68 ± 1.75a	6.64 ± 1.14a	3.40 ± 0.71a	4.55 ± 0.81a	63.13 ± 3.78b	6.60 ± 0.75a	379.02 ± 3.55a

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

TABLE 3: The total carotenoid, phenolic, and flavonoid content of wheat flour and quinoa flour.

	Total carotenoid (mg/100 g)	Total phenolic compound (mgGAE/100 g)	Total flavonoids (mg/100 g)
Wheat flour	0.10 ± 0.001b	30.18 ± 5.41b	11.17 ± 2.88b
Quinoa flour	1.45 ± 0.25a	66.45 ± 8.15a	32.14 ± 6.11a

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

TABLE 4: Water-holding capacity and oil-holding capacity of wheat flour and quinoa flour.

	Water-holding capacity (g H <sub>2</sub> O/g)	Oil-holding capacity (g oil/g)
Wheat flour	6.33 ± 0.22a	8.01 ± 0.66a
Quinoa flour	2.88 ± 0.07b	4.11 ± 0.65b

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

values than the values of quinoa flour. It is known that quinoa has expanded usages owing to its technological characteristics, such as solubility, gelation, water-holding capacity, and foaming, in addition to functional starch and omega-6, so it is appropriate to incorporate quinoa flour into wheat flour. The fiber of quinoa increased the water- and oil-holding capacities of the four mixtures, improving the dough and baked product quality [11, 30, 36].

The results in Table 5 show that the 12.5% quinoa biscuit and 25% quinoa biscuit had increased water absorption, arrival time, dough stability, and farinograph quality number values compared to the control biscuit. The highest farinograph parameters were observed in the 25% quinoa biscuits. These results were associated with hydrophilic carbohydrate, protein, and crude fiber contents in quinoa flour [28, 37–39]. In contrast, the obtained results disagreed with the decline in the arrival time, development, and stability of dough with increasing quinoa flour levels.

Increasing the quinoa flour in biscuit could increase extensibility, relative resistance, proportional number, and energy compared to the control biscuit. The values were highly significant in 25% quinoa biscuit. Also, relative resistance and proportional number were highly significant in 25% quinoa biscuit compared to the control biscuit, as represented in Table 6. The obtained results are correlated to

the dilution of an interrelated dough gluten matrix. In particular, biscuits have high proportions of fat and sugar and a short mixing phase, but the gluten network developed in the tested biscuits is related to an increase in the incorporation of the quinoa flour into the cookies and starch gelatinization [7, 40].

The data in Table 7 show nonsignificant differences in appearance, texture, color, and taste score and a significant lowered score of flavor and acceptability between 12.5% quinoa and control biscuits. The 25% quinoa biscuit had a significant decrease in the tested sensory characteristics compared with the control biscuit. The 25% quinoa biscuit showed significantly lower values of appearance, texture, color, and taste score and nonsignificant difference of flavor and acceptability compared to 12.5% quinoa biscuit. Generally, increasing the amount of quinoa flour in the biscuits affected their sensory evaluation due to the high levels of protein in quinoa flour, which affected the texture, flavor, and acceptability of the biscuits. These changes in sensory quality were attributed to the formation of hydrogen bonds among the hydroxyl carbonyl, amide hydroxyl groups, and polar groups of the other ingredients of the biscuit flour. Additionally, the increased protein content in quinoa flour formed tiny, compact bubbles in the dough structure, hence producing biscuit hardness [41, 42]. On the other hand, the

TABLE 5: Farinograph parameters of control biscuit, 12.5% quinoa biscuit, and 25% quinoa biscuit.

	Water absorption (%)	Arrival time (min)	Dough development time (min)	Dough stability (min)	Farinograph quality number
Control biscuit	56.61 ± 1.41c	1.30 ± 0.11c	3.01 ± 0.22b	4.32 ± 0.40b	132 ± 3.41c
12.5% quinoa biscuit	62.55 ± 2.14ab	2.23 ± 0.18b	4.31 ± 0.59ab	6.98 ± 1.11a	156 ± 4.98b
25% quinoa biscuit	67.01 ± 3.11a	3.55 ± 0.44a	5.03 ± 0.65a	7.35 ± 1.44a	167 ± 6.35a

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

TABLE 6: Extensograph parameters of control biscuit, 12.5% quinoa biscuit, and 25% quinoa biscuit.

	Extensibility (mm)	Relative resistance (BU)	Proportional number	Energy (cm <sup>2</sup> )
Control biscuit	163 ± 5.51c	490 ± 10.15c	2.75 ± 0.23b	108 ± 6.77c
12.5% quinoa biscuit	182 ± 4.57b	538 ± 8.61ab	3.41 ± 0.66a	119 ± 5.66b
25% quinoa biscuit	193 ± 2.15a	550 ± 6.71a	3.01 ± 0.44a	127 ± 2.11a

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

TABLE 7: Sensory evaluation of control biscuit, 12.5% quinoa biscuit, and 25% quinoa biscuit.

	Appearance	Texture	Color	Taste	Flavor	Acceptability
Control biscuit	8.10 ± 0.10a	8.10 ± 0.10a	8.20 ± 0.13a	8.24 ± 0.03a	8.10 ± 0.01a	8.04 ± 0.04a
12.5% quinoa biscuit	8.10 ± 0.10a	8.00 ± 0.01a	7.80 ± 0.15a	8.00 ± 0.00a	7.90 ± 0.10b	7.94 ± 0.04b
25% quinoa biscuit	7.70 ± 0.15b	7.50 ± 0.13ba	7.60 ± 0.16b	7.90 ± 0.23b	7.90 ± 0.18b	7.28 ± 0.11b

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

TABLE 8: Effect of the consumption of the 12.5% quinoa biscuit and 25% quinoa biscuit on body weight gain, weight gain%, food intake, and FER compared to control biscuit in diabetic rat groups.

Groups	Body weight gain (g)	Body weight gain (%)	Food intake (g)	FER
Positive control	25.71 ± 1.96c	21.42 ± 1.13c	17.40 ± 1.33a	0.0246 ± 0.002c
Control biscuit	23.55 ± 2.11cd	19.30 ± 0.77cd	17.33 ± 1.05a	0.0226 ± 0.001cd
12.5% quinoa biscuit	51.78 ± 4.66b	42.09 ± 3.21b	17.55 ± 1.21a	0.0491 ± 0.004b
25% quinoa biscuit	65.41 ± 5.40a	53.17 ± 4.03a	18.99 ± 1.10a	0.0574 ± 0.003a

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

addition of 50% or 100% quinoa flour addition biscuit formulations did not significantly change the biscuit properties compared to those made with wheat flour [43].

The results in Table 8 showed nonsignificant differences in body weight gain, body weight gain percent, and feed efficiency ratio (FER) between the diabetic positive rat group and the diabetic rat group that consumed control biscuit. On the other hand, the diabetic rat groups that consumed 12.5% quinoa biscuit and 25% quinoa biscuit showed a significant increase in body weight gain, body weight gain percent, and FER compared with the positive rat group. Among the experimental rat groups, the highest improvement in nutritional value appeared in the diabetic rat group that consumed 25% quinoa biscuits because of elevated lipid, protein, fiber, polyphenol, and antioxidant values compared to the control biscuit. The digestibility and absorption of nutrients were improved by quinoa fiber intake [44, 45]. Quinoa flour (QF) has been labelled a superfood because it contains more protein and has a better balanced amino acid composition than grain flours. QF is strong in protein, carbohydrate, fat, and fiber. Quinoa fiber is resistant to

enzymatic digestion and absorption in the small intestine but generally ferments entirely or partially in the large intestine. Dietary fiber is regarded to be necessary for excellent digestive health as well as a number of physiological benefits. Dietary fiber has been shown to reduce cholesterol and fat absorption, change postprandial insulin response, increase endogenous cholesterol conversion to bile acids, improve intestinal microbiota, and reduce the incidence and severity of gastrointestinal infection and inflammation [41]. Several prior studies in vitro have demonstrated that quinoa protein digestibility is higher than wheat protein digestion, which adds to its high stomach accessibility and digestion, as well as its health benefits [46].

The consumption of the tested biscuits showed a nonsignificant difference in blood hemoglobin in diabetic rat groups. Rats that consumed in the control group showed nonsignificant differences in glycosylated hemoglobin, insulin, and glucose compared with the positive control diabetic rat group. Following consumption of 12.5% quinoa biscuits and 25% quinoa biscuits for 60 days, there was a decline in blood glycosylated hemoglobin and glucose and

TABLE 9: Effect of consumption of the 12.5% quinoa biscuit and 25% quinoa biscuit on hemoglobin, glycosylated hemoglobin, insulin, and glucose compared to control biscuit in diabetic rat groups.

Groups	Hemoglobin (g/dl)	Glycosylated hemoglobin (%)	Insulin (ng/d)	Glucose (mg/dl)
Positive control	12.66 ± 1.21a	8.07 ± 1.03a	1.44 ± 0.14cd	295.11 ± 8.65a
Control biscuit	12.77 ± 1.09a	7.96 ± 0.78ab	1.54 ± 0.15c	289.98 ± 9.70ab
12.5% quinoa biscuit	13.75 ± 1.22a	6.11 ± 0.69c	2.08 ± 0.30b	129.66 ± 7.33c
25% quinoa biscuit	13.70 ± 1.13a	5.05 ± 0.55d	2.97 ± 0.42a	105.71 ± 5.14d

Mean values in each column having the same letter (a and b) are nonsignificantly different at  $P > 0.05$ .

an elevation in insulin compared with the positive control diabetic rat group. Moreover, the 25% quinoa biscuit rat group showed noticeable improvement in blood diabetic indicators, as shown in Table 9. The addition of quinoa flour to biscuits could increase the availability of fiber, which reduces the levels of blood lipids and glucose and elevates insulin sensitivity [47]. The intake of slowly digestible starches in whole grain flours from legumes and pseudocereals could lower glycemic indexes. The incorporation of quinoa flour into biscuits is beneficial in reducing glucose and increasing insulin without disturbing the nutritional balance owing to high phenol, fiber, and antioxidant activity. Quinoa seeds have anti-inflammatory, antioxidant, and antitumor actions due to the presence of valuable phenolic compounds [48–50].

#### 4. Conclusions

Incorporation of quinoa flour is beneficial for biscuit production to improve the rheological, technological, and sensory properties of biscuits because of the higher quantity of dietary fiber in addition to high nutritional values (protein, fiber, and other bioactive antioxidant compounds) and therapeutic value due to the hypoglycemic effect.

**4.1. Recommendations.** Regarding the results of our study, it is recommended to fortify bakery products, especially biscuits with quinoa flour, and advise their consumption by diabetic patients. Further studies are needed to produce products fortified with quinoa and sugar alternatives for diabetic patients.

#### Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

#### Additional Points

**Highlights.** (i) Quinoa is a new crop species with high nutritional value, so it acts as a complete food. (ii) Quinoa is incorporated into wheat flour at a definite percentage for biscuit production. (iii) It has been of interest to increase the nutritional and sensory quality of biscuits by incorporating functional foods to decline blood glycosylated hemoglobin and glucose and for an elevation in insulin level in the diabetic rat group.

#### Conflicts of Interest

The authors declare no conflicts of interest.

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