Quality attribute and nutritive value of barley muffin upon addition of different functional ingredients

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Abstract

Muffins are sweet baked products highly appreciated by consumers due to their soft texture and characteristic taste. This study aimed to evaluate the effect of using different levels of functional ingredients: soybean flour (SF), quinoa flour (QF), and carob seed powder (CSP), individually and in combination—on the quality and nutritive value of barley muffins .The results revealed a significant increase (P<0.05) in water absorption capacity with the addition of 3% CSP compared to other treatments (10% SF, 10% QF) and the control. Muffins with 10% SF showed a significant (P<0.05) increase in volume compared to other treatments and the control. Tenderness improved significantly with individual treatments of 5% SF, 10% SF, 5% QF, 10% QF, 1% CSP, and 3% CSP. Notably, combinations of 5% SF + 1% CSP and 5% SF + 5% QF also significantly enhanced tenderness compared to the control. Sensory evaluation indicated that muffins treated individually with 5% SF, 5% QF, or 1% CSP received significantly higher scores (P<0.05). The combination of 5% SF + 5% QF maintained higher acceptability than other treatments. This formulation also showed increased calcium and iron content compared to the control. Moreover, product stability was significantly enhanced with the 5% SF + 5% QF and 1% CSP treatments throughout storage at 25°C for 7 days. The study suggests that partial substitution with 5% SF, 5% QF, or 1% CSP individually or in combination can improve the quality, stability, and nutritional value of barley muffins.

Keywords: Functional food, muffin, barley, soybean, quinoa, carob seeds.

Introduction

Functional foods are rich sources of many bioactive compounds with health-promoting properties. To date, epidemiological evidence obtained from observational studies and clinical trials has demonstrated that the regular consumption of nutrient-rich foods, particularly those of plant origin, can increase vitality, benefit overall health, and reduce the risk of chronic disease (**Jurek, 2022**). Barley is the fourth largest cereal crop in the world after wheat, corn, and rice. Barley is receiving more attention from both agricultural and food scientists, because of its special chemical composition and health benefits. It can serve as food that meets the needs of a diet low in calories, high in fiber, and rich in prebiotics, which has led to barley being listed as a desirable healthy food **(Geng *et al.,* 2022).**

It was found that using barley flour only has limitations for making various barley flour-based food products, due to the unsuitable physical properties of barley flour. The barley product became darker in color, non-uniform in shape, harder in texture, and unacceptable in quality for the consumer (**Ereifej *et al.,* 2007 and Punia *et al.*, 2022)**. Investigators recommended looking at possible future trends in the improved nutrition and qualities of barley products (**Holtekjolen *et al.,* 2008 and Abdul *et al.*, 2022**).

Soybean is considered to be an excellent source of manganese, phosphorus, and protein as well as a good source of iron, omega-3 fatty acids, and dietary fiber. Soy flour is used as an ingredient in foods, beverages, and condiments to promote higher optimal health benefit **(Uwem *et al.,* 2017).** Quinoa is a pseudocereal with high nutritional value. It is a good source of protein, carbohydrates, fiber, vitamins, and minerals, which makes it a great food choice for human health (**Ng and Wang, 2021).**

Hydrocolloids (gums) have good functional characteristics, such as emulsifying, gelling, solubility, and textural improvement. In bakery products, hydrocolloids are used to improve dough performance, bread and cake characteristics, sensorial quality, and product shelf life (**Salehi, 2020).** Carob seeds are used to produce locust bean gum (LBG), which can be used as a thickener, hydrocolloid, stabilizer, emulsifier, and gelling agent in the food industry. It is approved in most areas of the world and is chemically known as E410. LBG improves the overall quality of finished baked products (**Palaiogianni *et al.,* 2022**).

Health and nutritional virtues have become the focal point in new product development due to increasing consumer awareness who desire to remain healthy and fit. Baked products like muffins are veritably popular, because they are consumed at breakfast or as a snack. Muffins are sweet baked products highly appreciated by consumers, because of their soft texture and characteristic taste. Muffins are cereal-based bakery products characterized by a typical porous structure and high volume, which confer a spongy texture. People from all age groups can be served muffins as breakfast or snacks, because they come in a variety of sizes, shapes, and flavors **(Shukla *et al.*, 2024).**

The aim of the present study was to evaluate the effect of different levels of functional ingredients: soybean flour (SF), quinoa flour (QF), carob seeds powder (CSP) individually and in combinations on improving quality attribute, storage stability and nutritive value of barley muffin.

Materials and Methods

Materials:

Barley grains (*Hordeum vulgare L.*) and Soybean (*Glycine max L. Merr*) flour were purchased from Agricultural Research Center, Giza, Egypt. Quinoa (*Chenopodium quinoa Willd*), carob seeds (*Ceratonia siliqua L.*), and all the other ingredients that were used for barley muffin preparation were purchased from local market, Giza, Egypt. Chemicals used for proximate chemical determination were purchased from Al-Gomhoria Chemical Company, Cairo, Egypt.

Methods:

A. **Chemical analysis of raw materials:** Barley flour, soybean flour, quinoa flour, and carob seeds powder were subjected to chemical analysis to determine their proximal composition: moisture, protein, fat, carbohydrate, fiber, and ash according to methods of **AOAC (2023)**.
B. **Ingredients and method for Muffin preparation:**

- **Preparation of barley flour:** Barley grains were ground in a local mill, and the resulting flour was sieved to remove bran.
- **Preparation of quinoa flour:** Quinoa was milled, and the resulting flour was sieved to obtain quinoa flour.

- **Preparation of carob seeds powder:** Carob seeds were ground, and the resulting powder was sieved to remove the outer dark fiber to obtain excellent powder.

C. Barley muffin products preparation:

Barley muffin was prepared according to the method reported by **Punia *et al.* (2022)** with some modifications, where butter was replaced with sunflower oil, and vanilla was used in this recipe. Products preparation were done in Food Science Lab at Department of Nutrition and Food Science, Faculty of Home Economics, Helwan University, Cairo, Egypt. The muffin recipe was as the followings: 100 g barley flour or its blends, 50 g sunflower oil, 50 g sugar, 50 g eggs, 50 g milk, 3.30 g baking powder, 0.40 g salt, and 1 g vanilla. Eggs and vanilla were beaten, then sunflower oil, sugar, and half of the milk were added to the mixture and well beaten. After that, barley flour or its blends, baking powder, and salt were added and mixed properly with the rest of the milk added gradually to produce uniform batter. Batter (60 g) was poured into muffin molds and baked at 190 ° C for 24 min. The experiment design with the functional ingredients is presented in **Table (1).** Muffin samples for each treatment were subjected to different methods for quality evaluation.

Table (1): Barley muffin products fortified with different percentages of functional ingredients (soybean flour, quinoa flour, carob seeds powder) individually and in combinations.

Muffin	Functional ingredients					
	Soybean flour		Quinoa flour		Carob seeds powder	
	5%	10%	5%	10%	1%	3%
Barley (Control): without addition of functional ingredients under investigations						
Barley + Soybean (SF)	*	*				
Barley + Quinoa (QF)			*	*		
Barley + Carob seeds (CSP)					*	*
Barley + Soybean + Quinoa	*		*			
Barley + Soybean + Carob seeds	*				*	
Barley + Quinoa + Carob seeds			*		*	

D. Quality evaluation of barley muffin products:

1. Physical evaluation (parameter measurements):

Physical parameter measurements were done in triplicates for barley muffin treatments and the control sample according to methods reported by **Penfield and Campbell (1990)**. The parameters recorded included: water absorption capacity (WAC) during dough preparation, dough weight (wt,) before and after baking (gm), percentage change (%) in weight was calculated by using the following equation=

$$\frac{\text{weight before baking (g) - weight after baking (g)}}{\text{weight before baking (g)}} \times 100$$

Product's volume (cm^3) was determined by displacement method, product's density (g/cm^3) was calculated by using an equation=

$$\frac{\text{weight (g)}}{\text{volume (cm}^3\text{)}}$$

Height (cm), index to volume (cm), product area (cm^2) was measured using digital planimeter instrument, and product tenderness was measured using universal penetrometer instrument (mm/sec). All physical parameters measurement were carried out in the Food Science Lab at Department of Nutrition and Food Science, Faculty of Home Economics, Helwan University, Cairo, Egypt.

2. Sensory evaluation:

The prepared barley muffin with each treatment as well as the control samples, were subjected to sensory evaluation according to **Penfield and Campbell (1990)** by 15 panelists (using a score sheet) at Food Technology Department, National Research Center, Dokki, Giza, Egypt. The evaluated characteristics included: Appearance, external color, internal color, taste, odor, degree of tenderness, cell size and homogeneity, and overall acceptability.

3. Proximate chemical composition of the final muffin product:

Proximal compositions of the final muffin product that achieved better characteristics: (moisture, protein, fat, carbohydrate, fiber, and ash) were determined according to methods of **AOAC (2023)** for the final products of each treatment that achieved better characteristics (individual and in combination). The determination was done at Food Technology Department, National Research Center, Dokki, Giza, Egypt, also minerals composition (calcium, zinc, and iron) were determined using Atomic Absorption Spectrophotometer ICE 3500 series (Thermo) according to **Abdel-Rahman *et al.* (2018)** at Food Toxicology and Contaminants Department, National Research Center, Dokki, Giza, Egypt.

4. Product stability under storage conditions:

The final barley muffin products stability of each treatment that achieved better characteristics (individual and in combination) as well as the control sample were subjected to investigation under storage condition (25°C for 7 days). Product tenderness after the storage period was measured using universal penetrometer instrument (mm/sec) according to **Penfield and Campbell (1990)** at the Food Science Lab, Department of Nutrition and Food Science, Faculty of Home Economics, Helwan University, Cairo, Egypt.

Statistical Analysis:

The data of this study was analyzed using SPSS version 16, USA. A one-way analysis of variance ($p \leq 0.05$) was performed to identify significant differences among all studies' parameters **(SPSS, 2007).** Means was calculated using the Duncan multiple ranges test **(Duncan, 1955).**

Results and Discussion

Chemical analysis of raw materials:

The results in **Table (2).** Show that SF contains the highest protein content (42.26%), followed by QSF (36.74%). Fat content was high in both QF and CSP (5.81 and 4.22%, respectively). Fiber content was high in CSP (9.53%), followed by QF and SF (5.08 and 4.06%, respectively). The highest content of ash found in SF (8.25%), followed by CSP (6.40%). According to **Uwem *et al.* (2017)** soybeans had the highest value of crude protein, which can be considered a good source of protein, amongst many other plant-based foods. Also is a good source of ash and fiber. **El-Sebeay and Hafez (2018)** found that quinoa had 16.4 % protein, 8.2 % fat, and 3.8 % fiber. In addition, the percentage of protein in quinoa is higher on average than that in barley.

Table (2): Chemical composition of barley flour and the functional ingredients.

Item	Moisture (%)	Component, % on DM basis				
		Protein	Fat	Carbohydrate	Fiber	Ash
Barley flour	9.69	9.20	1.55	84.51	2.82	1.92
Soybean flour (SF)	8.43	42.26	0.53	44.90	4.06	8.25
Quinoa flour (QF)	9.96	13.06	5.81	73.03	5.08	3.02
Carob seeds powder (CSP)	8.32	36.74	4.22	43.11	9.53	6.40

Physical parameters evaluation of barley muffin products:

The results on **Tables (3a and b),** show the following results for individual and in combination functional ingredients treatments: values of water absorption capacity of both barley muffin with 10% SF and the control sample were recorded to be the same (60.00 gm). No significant differences (P<0.05) were detected in dough weight before and after baking among the three muffins treatments. Percentage changes (%) in weight were significantly decreased (P<0.05) in both 5 and 10 % SF barley muffin (12.21 to 11.66%). The highest volume (P<0.05) was found in muffin with 10%SF, followed by 5% SF muffin. The product density value (g/cm$^{3)}$ of control was (0.34 g/cm^3), which was found to be significantly different (P<0.05) than 5% SF barley muffin (0.26 g/cm^3). Height increased (P<0.05) significantly (3.86 and 3.90 cm, respectively) for 10%SF barley muffin and control compared with 5% SF (3.71). Index to volume of control muffin was higher significantly (P<0.05) than that of both 5% SF and 10% SF barley muffin. Product area decreased (P<0.05) significantly (from 24.14 to 22.53 cm^2 in 5%SF) and (from 24.14 to 22.96 cm^2 in 10%SF).

Product tenderness was found to be at the highest value (P<0.05) in 10% SF (49.89 mm/sec), followed by 5% SF muffin (45.20 mm/sec) respectively).

Ho and Halim (2019) stated that SF had a high water absorption in batter during mixing. It can hold and bind large amounts of water, thus improving moisture retention and retaining the tenderness in cake, therefore giving a higher yield of end products. Cakes made of SF showed the significantly highest volume. This was attributed to the hydrophobic properties of proteins from SF, which influences the development of cakes. Cakes prepared with partial substitution of SF for all-purpose flour were found to enhance physical properties (weight, volume, and density).

In QF treatments: Water absorption capacity was decreased significantly (P<0.05) in both 5% QF and 10% QF (60.00 compared to control 50.00 g, respectively). No significant differences (P<0.05) were detected in dough weight before and after baking among the three muffins treatments. Dough weight after baking increased (P<0.05) significantly (from 52.66 to 53.00 g in 5% QF and from 53.66 g in 10% QF). Change percentages (%) in weight were found to significantly (P<0.05) difference among the three muffins treatments. There were significant differences (P<0.05) among the three muffins with regard to product volume. Product density was increased significantly (P<0.05) in 5% QF (from 0.35 to 0.39 g/cm^3) than that of the other treatments. Both 5%QF and 10%QF muffins had the highest value for height which is significantly (P<0.05) higher than the other treatments values. The highest value of product tenderness was found in 10% QF muffin (45.73), followed by 5%QF muffin (41.33), compared with (40.66 mm/sec) for the control. The cake without quinoa flour exhibited the highest hardness value, and the addition of quinoa flour caused a significant decrease in the hardness of the cake. The quinoa flour addition significantly increased the density of the cake. Because of that, an increase in the density of the cakes can be associated with a decrease in the volume of cakes (**Bozdogan *et al.*, 2019**).

In CSP treatments: The 3%CSP muffin was recorded the highest value (P<0.05) in water absorption capacity, and the lowest recorded with 1%CSP muffin. No significant differences in dough weight before and after baking among the three muffins treatments. Percentages change (%) in weight was significantly higher (P<0.05) in 1%CSP muffin compared with the other treatments. There was a significant difference among the three muffin samples with regard to volume. The product density results showed the same value in both 1%CSP and 3%CSP muffin (0.42 g/cm^3) , which was found to be higher than control (0.36 g/cm^3). Product area was (P<0.05) decreased for 3%CSP muffin compared with the control. The highest value of product tenderness was recorded with 3%CSP muffin (50.93 mm/sec) compared with control (41.00 mm/sec). **Barak and Mudgil (2014)** reported that the addition of locust bean gum to wheat flour increased the water absorption capacity and improves the final texture. Locust bean gum “carob gum” can also be used as a binding agent as a substitute for gluten in gluten-free products formulations based on corn starch with improved loaf volume and crumb structure. Products’ tenderness increased upon individual treatments with each of: 5%SF, 10%SF, 5%QF,10%QF, 1%CSP and 3%CSP in comparison to that of the control muffin.

The overall results of the functional effect of individual ingredients treatments revealed that: the 3% CSP increased water absorption capacity (WAC) (g) of barley muffin more than the effects of each of 10%SF and 10%QF treatments as well as the control muffin. On the other hand, all the three ingredient treatments enhanced dough weight after baking (g) more than that of the control. However, 10%SF increased product volume (cm^3) significantly ($P<0.05$) in comparison to the other treatments (10%QF and 3% CSP) and the control. Products tenderness increased upon individual treatments with each of: 5%SF ,10%SF, 5%QF,10%QF, 1%CSP and 3%CSP in comparison to that of the control muffin.

The results of combination ingredients treatment **Table (3a and b).** revealed the following: Water absorption capacity was the same in both control sample and the (5%SF+1%CSP) muffins (60.00 g), the lowest water absorption capacity was found with treatment of (5%QF+1%CSP) muffin (50.00 g). No significant differences in dough weight before and after baking among the three muffins. Percentage changes (%) in weight was the same (12.21%) in both control and 5%SF+5%QF muffins and was found to be higher significantly ($P<0.05$) than (5%SF+1%CSP) and (5%QF+1%CSP) muffins (11.66%). There was a significant difference ($P<0.05$) among the three muffins in volume, the highest value recorded with control. Product density decreased significantly ($P<0.05$) in all combination treatments compared with the control. There was no significant difference was detected between control and both (5%SF+5%QF) and (5%QF+1CSP) muffin in index to volume values. Product’s area (cm^2) was decreased significantly ($P<0.05$) in all combination treatments compared with the control. The highest value ($P<0.05$) of product tenderness (mm/sec) was noticed with (5%SF+1%CSP) muffin (55.26 mm/sec), followed by (5%SF+5%QF) muffin (50.20) in comparison to both (5%QF+1CSP) and control).

Table (3a): Physical parameters of barley muffin product treatments upon addition of functional ingredients individual and in combinations (mean± SE).

Treatment		Water absorption capacity (WAC) (g)	Dough weight before baking (g)	Dough weight after baking (g)	Change % in weight (%)	Volume (cm^3)
Soybean flour treatment	Control	60.00^{a}±0.00	60.00^{NS}	52.66^{NS}±0.20	12.21^{a}±0.10	150.66^{c}±1.03
	5%SF	55.00^{b}±0.00	60.00^{NS}	53.00^{NS}±0.00	11.66^{b}±0.00	196.33^{b}±1.02
	10%SF	60.00^{a}±0.00	60.00^{NS}	53.00^{NS}±0.00	11.66^{b}±0.00	203.33^{a}±1.10
Quinoa flour treatment	Control	60.00^{a}±0.00	60.00^{NS}	52.66^{b}±0.01	12.21^{a}±0.10	148.66^{a}±1.25
	5%QF	50.00^{b}±0.00	60.00^{NS}	53.00^{a}±0.01	11.66^{b}±0.20	134.00^{c}±1.33
	10%QF	50.00^{b}±0.00	60.00^{NS}	53.66^{a}±0.02	10.55^{c}±0.10	138.33^{b}±1.29
Carob seeds powder treatment	Control	60.00^{b}±0.00	60.00^{NS}	52.66^{a}±0.04	12.21^{b}±0.10	143.00^{a}±1.01
	1%CSP	55.00^{c}±0.00	60.00^{NS}	52.00^{b}±0.00	13.33^{a}±0.10	121.00^{c}±1.11
	3%CSP	65.00^{a}±0.00	60.00^{NS}	53.00^{a}±0.00	11.66^{c}±0.10	124.33^{b}±1.15
Combination treatment	Control	60.00^{a}±0.00	60.00^{NS}	52.66^{NS}±0.01	12.21^{a}±0.01	141.33^{a}±1.21
	5%SF+ 5%QF	55.00^{b}±0.00	60.00^{NS}	52.66^{NS}±0.01	12.21^{a}±0.02	120.33^{c}±1.36
	5%SF+ 1%CSP	60.00^{a}±0.00	60.00^{NS}	53.00^{NS}±0.00	11.66^{b}±0.00	121.00^{c}±1.29
	5%QF+ 1%CSP	50.00^{c}±0.00	60.00^{NS}	53.00^{NS}±0.00	11.66^{b}±0.00	126.66^{b}±1.22

SF: Soybean flour, QF: Quinoa flour, CSP: Carob seeds powder.
Values in the same column with various superscript letters are significantly different at ($P < 0.05$).
NS: Non-significant differences.

Table (3b): Some physical parameters of barley muffin treatments upon addition of functional ingredients individual and in combinations (mean± SE).

Treatment		Density (g/cm^3)	Height (cm)	Index to volume (cm)	Product area (cm^2)	Product tenderness (mm/sec)
Soybean flour treatment	Control	0.34^{a}±0.02	3.86^{a}±0.04	4.68^{a}±0.30	24.14^{a}±0.41	40.86^{c}±1.22
	5%SF	0.26^{b}±0.04	3.71^{b}±0.05	4.50^{b}±0.20	22.53^{b}±0.62	45.20^{b}±1.35
	10%SF	0.25^{b}±0.03	3.90^{a}±0.03	4.52^{b}±0.40	22.96^{b}±0.71	49.86^{a}±1.28
Quinoa flour treatment	Control	0.35^{b}±0.02	3.79^{b}±0.20	4.60^{a}±0.10	23.89^{a}±0.63	40.66^{c}±1.01
	5%QF	0.39^{a}±0.03	3.90^{a}±0.30	4.48^{b}±0.20	22.88^{b}±0.68	41.33^{b}±1.04
	10%QF	0.38^{a}±0.02	4.01^{a}±0.40	4.58^{a}±0.30	23.41^{ab}±0.74	45.73^{a}±1.06
Carob seeds powder treatment	Control	0.36^{b}±0.03	3.68^{a}±0.04	4.60^{NS}±0.01	23.14^{a}±1.21	41.00^{b}±1.28
	1%CSP	0.42^{a}±0.01	3.61^{a}±0.03	4.56^{NS}±0.01	22.96^{a}±1.33	49.33^{a}±1.30
	3%CSP	0.42^{a}±0.02	3.54^{b}±0.05	4.52^{NS}±0.00	22.20^{b}±1.41	50.93^{a}±1.26
Combination treatment	Control	0.73^{a}±0.10	3.56^{a}±0.18	4.44^{a}±0.10	22.28^{a}±1.28	40.93^{d}±1.33
	5%SF+5 %QF	0.43^{b}±0.11	3.63^{a}±0.17	4.44^{a}±0.20	21.83^{b}±1.27	50.20^{b}±1.35
	5%SF+1 %CSP	0.43^{b}±0.13	3.51^{b}±0.15	4.37^{b}±0.30	21.38^{c}±1.34	55.26^{a}±1.48
	5%QF+1 %CSP	0.41^{c}±0.11	3.56^{a}±0.16	4.40^{a}±0.40	21.60^{b}±1.30	48.73^{c}±1.41

SF: Soybean flour, QF: Quinoa flour, CSP: Carob seeds powder.
Values in the same column with various superscript letters are significantly different at ($P < 0.05$).
NS: Non-significant differences.

Sensory evaluation:

The results on **Table (4a and b),** show the following: in SF treatments: appearance score increased significantly (P<0.05) in 10%SF and 5%SF muffins (4.26 and 4.20) treatments compared to the control (4.06). The external color was (P<0.05) higher in 5%SF muffin compared with the other treatments. There were no significant differences in internal color among the three muffins treatments. Taste and odor (mean score value) of control muffin was found to be the highest (P<0.05), followed by 5%SF muffin. The degree of tenderness increased significantly (P<0.05) in 5%SF and 10%SF muffins treatments (4.26 and 4.20, respectively) than that of control sample (3.93). Both barley muffins 5%SF (4.26) and 10%SF (4.00) had significantly (P<0.05) higher score with regard to cell size and homogeneity than control (3.73). The highest mean value of overall acceptability was found with 5%SF muffin. At 5% level of soybean flour, fortification barley muffin had higher scores for all the evaluated sensory characteristics. According to **Akter *et al.* (2021)** the flavor of cake decreased with increasing in the substitution of soybean flour. This could be due to the flavor of soy flour. The score for taste had decreased with an increase in the level of substitution of soy flour. For the overall acceptability, 5% and 10% of soy flour added cake had the highest value.

In quinoa flour treatments: The significant highest (P<0.05) mean value of appearance was recorded with control muffin (4.36), followed by 5%QF muffin (3.80), and the same observation with regard to in external color (4.33) for control and 3.80 for 5%QF muffin. There were no significant differences in internal color among the three muffins treatments. On the other hand, taste score of 10%QF (4.03) and control (4.00) muffins were (P<0.05) higher compared to 5%QF muffin (3.80). Odor increased significantly (P<0.05) in 10%SF and 5%SF muffins (4.06 and 4.03, respectively) compared with control (3.83). The score for degree of tenderness (P<0.05) decreased (3.66) for 5% QF muffin compared with the other treatments. Products' cell size and homogeneity results showed no significant difference between control and 5%QF muffins. The acceptability of 5%QF was higher significantly than 4.06, followed by 10%QF muffin (3.80). The 5% level of quinoa flour, fortification barley muffin had acceptable scores for all evaluated sensory characteristics. **Aly and Sadeek (2018)** found that no significant difference was observed in terms of taste and flavor between the control (wheat flour) and 10% quinoa cakes. This could probably be due to the nature of quinoa flour, which did not impart any additional flavor to the cakes.

In CSP treatments: The control muffin had higher significant score (P<0.05) for appearance (4.56), followed by 1% CSP muffin (3.96), then 3.43 for 3%CSP. The score of external and internal color were significantly decreased (P<0.05) by addition of each of 1% and 3% CSP compared with control. Taste mean score decreased significantly with 1%CSP (3.93) and with 3%CSP (3.53) muffin compared with control (4.16). The score of odor was higher significantly (P<0.05) in control muffin (4.23), followed by 1%CSP muffin (3.90), followed by 3%CSP (3.33). There were significant higher values (P<0.05) for degree of tenderness and cell size and homogeneity for control muffin, followed by 1%CSP muffin. Overall acceptability was high in control muffin (4.30), followed by 1%CSP muffin (4.06). At 1% level of carob seeds powder, fortification barley muffin had acceptable scores for all sensory characteristics evaluated after the control muffin. **Salehi (2019)** stated that gums can improve food taste and texture, retard starch retrogradation, improve moisture retention, and enhance the overall quality of the gluten-free cakes. Positive effects in cakes of seeds gums (like locust bean “carob”) have been reported, at level 1% flour basis.

In combination treatments: Appearance mean value was (P<0.05) increased in (5%SF+5%QF) muffin (4.50), followed by (5%SF+1%CSP) muffin (4.20). The highest significant value of external color was recorded with (5%SF+5%QF) muffin (4.56). Internal color score decreased significantly (3.73) for 5%SF+1%CSP muffin. The score of taste was (P<0.05) decreased with 5%QF+1%CSP compared with the other muffin treatments. Odor value was decreased significantly (P<0.05) for (5%SF+1CSP) and (5%QF+1%CSP) muffins compared with the other samples. Degree of tenderness (mm/sec) and cell size homogeneity significantly (P<0.05) decreased for (5%SF+1%CSP) and (5%QF+1%CSP) compared with the other muffin samples. The overall acceptability mean score for (5%SF+5%QF), and control were higher significantly (P<0.05) than the other samples. The combination of (5% SF + 5% QF) in fortified barley muffin had acceptable scores for all evaluated sensory characteristics.

The overall results of the functional effect of individual ingredients treatments revealed that: The 5% level of SF, fortification barley muffin had higher scores for all the evaluated sensory characteristics, followed by 5% level of QF, which had acceptable scores for all sensory characteristics. At 1% level of CSP, fortification barley muffin had more acceptable scores for all sensory characteristics than 3% of carob seeds powder. The results of combination ingredients treatment revealed that: The combination of (5% SF + 5% QF) in fortified barley muffin had more acceptable scores for all evaluated sensory characteristics than other combination treatments. **Figure (1)** showed the final products of muffin which achieved better characteristics in individually and in combination treatments.

Table (4a): Sensory evaluation of barley muffin products treatments upon addition of functional ingredients individual and in combinations (mean±SE).

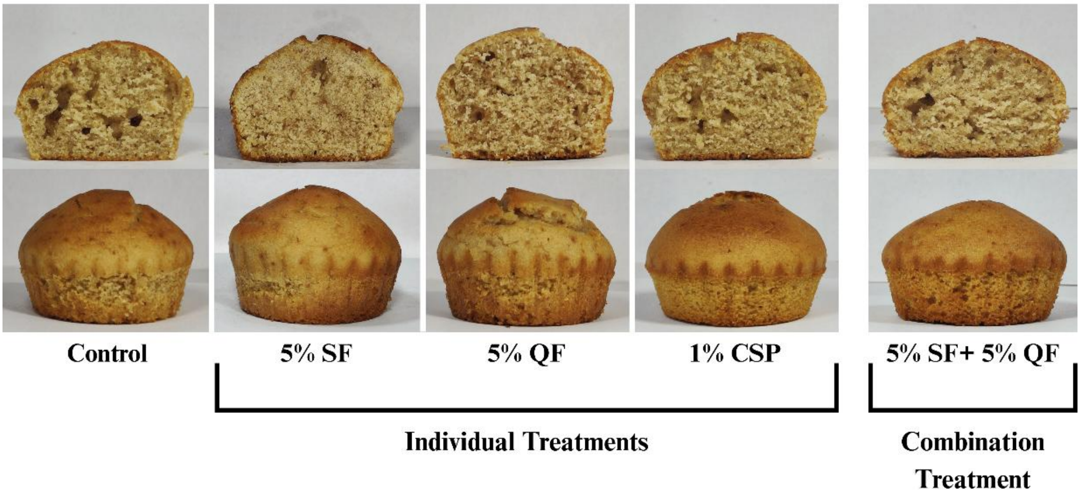
Treatment		Appearance	External color	Internal color	Taste	Odor
Soybean flour treatment	Control	$4.06^{b}\pm0.34$	$4.23^{b}\pm0.32$	$3.90^{NS}\pm0.29$	$4.10^{a}\pm0.31$	$4.36^{a}\pm0.32$
	5%SF	$4.20^{a}\pm0.33$	$4.40^{a}\pm0.34$	$3.96^{NS}\pm0.28$	$3.73^{b}\pm0.27$	$3.86^{b}\pm0.28$
	10%SF	$4.26^{a}\pm0.31$	$4.23^{b}\pm0.32$	$3.83^{NS}\pm0.29$	$3.56^{c}\pm0.26$	$3.76^{c}\pm0.29$
Quinoa flour treatment	Control	$4.36^{a}\pm0.34$	$4.33^{a}\pm0.35$	$3.83^{NS}\pm0.26$	$4.00^{a}\pm0.31$	$3.83^{b}\pm0.29$
	5%QF	$3.80^{b}\pm0.25$	$3.80^{b}\pm0.25$	$3.90^{NS}\pm0.27$	$3.80^{b}\pm0.28$	$4.03^{a}\pm0.33$
	10%QF	$3.63^{c}\pm0.26$	$3.73^{bc}\pm0.26$	$3.76^{NS}\pm0.24$	$4.03^{a}\pm0.31$	$4.06^{a}\pm0.32$
Carob seeds powder treatment	Control	$4.56^{a}\pm0.33$	$4.50^{a}\pm0.35$	$4.26^{a}\pm0.34$	$4.16^{a}\pm0.33$	$4.23^{a}\pm0.36$
	1%CSP	$3.96^{b}\pm0.24$	$4.10^{b}\pm0.34$	$4.00^{b}\pm0.31$	$3.93^{b}\pm0.27$	$3.90^{b}\pm0.25$
	3%CSP	$3.43^{c}\pm0.26$	$3.56^{c}\pm0.26$	$3.30^{c}\pm0.28$	$3.53^{c}\pm0.29$	$3.33^{c}\pm0.26$
Combination treatment	Control	$4.13^{b}\pm0.35$	$4.26^{b}\pm0.34$	$4.00^{a}\pm0.31$	$4.16^{a}\pm0.34$	$4.20^{a}\pm0.34$
	5%SF+5%QF	$4.50^{a}\pm0.33$	$4.56^{a}\pm0.36$	$3.90^{a}\pm0.27$	$4.20^{a}\pm0.33$	$4.20^{a}\pm0.34$
	5%SF+1%CSP	$4.20^{b}\pm0.34$	$4.43^{a}\pm0.33$	$3.73^{b}\pm0.28$	$4.06^{a}\pm0.31$	$3.96^{b}\pm0.28$
	5%QF+1%CSP	$3.76^{c}\pm0.25$	$4.26^{b}\pm0.31$	$3.86^{a}\pm0.29$	$3.73^{b}\pm0.27$	$3.96^{b}\pm0.27$

SF: Soybean flour, QF: Quinoa flour, CSP: Carob seeds powder.
Values in the same column with various superscript letters are significantly different at ($P < 0.05$).
NS: Non-significant differences.

Table (4b): Some sensory evaluation of barley muffin products treatments upon addition of functional ingredients individual and in combinations (mean±SE).

Treatment		Degree of tenderness	Cell size and homogeneity	Overall acceptability
Soybean flour treatment	Control	3.93^{b}±0.29	3.73^{b}±0.28	4.03^{a}±0.33
	5%SF	4.26^{a}±0.35	4.26^{a}±0.34	4.20^{a}±0.35
	10%SF	4.20^{a}±0.33	4.00^{a}±0.30	3.70^{b}±0.28
Quinoa flour treatment	Control	4.06^{a}±0.32	3.73^{a}±0.26	4.00^{a}±0.30
	5%QF	3.66^{b}±0.25	3.60^{a}±0.22	4.06^{a}±0.29
	10%QF	3.96^{a}±0.28	3.46^{b}±0.25	3.80^{b}±0.34
Carob seeds powder treatment	Control	4.36^{a}±0.34	4.30^{a}±0.34	4.30^{a}±0.33
	1%CSP	3.60^{b}±0.25	3.70^{b}±0.26	4.06^{a}±0.31
	3%CSP	2.96^{c}±0.21	2.83^{c}±0.22	3.10^{b}±0.29
Combination treatment	Control	4.16^{a}±0.35	4.00^{a}±0.32	4.23^{a}±0.36
	5%SF+5%QF	4.06^{a}±0.33	4.00^{a}±0.33	4.16^{a}±0.34
	5%SF+1%CSP	3.96^{ab}±0.24	3.90^{ab}±0.27	3.86^{b}±0.26
	5%QF+1%CSP	3.60^{b}±0.25	3.56^{b}±0.27	3.66^{c}±0.25

SF: Soybean flour, QF: Quinoa flour, CSP: Carob seeds powder.
Values in the same column with various superscript letters are significantly different at ($P < 0.05$).



(SF) Soybean flour, (QF) Quinoa flour, (CSP) Carob seeds powder

Figure (1): Photo structure of barley muffin products that achieved better characteristics after treated with individual and combination of functional ingredients.

The proximate chemical composition of the final muffin products:

The results of muffin products that achieved better characteristics are presented in **Table (5).** There was significant increase in protein content of 5% SF muffin (14.65%), and of 5% QF muffin (12.38%) compared to control (10.77%) muffin. Fat content for 5% SF muffin was significantly ($P<0.05$) higher compared to that of the control muffin (28.91%), followed by 5% QF muffin (28.21%) compared with (26.48%) for control. The 5% QF and 5 %SF muffins had significantly ($P<0.05$) lower percentage of carbohydrate content (23.37 and 20.56%, respectively) control muffin (26.82%). There were no significant differences between 5% SF, 1% CSP, (5% SF+5% QF), and control muffins with regard to fiber content. There was a significant increase in ash content of 5 %SF muffin (2.75%) compared to 1.83% for the control sample. These results were agreed with the reported results by **Ho and Halim (2019),** who found that soybean flour significantly improved nutritional values of cake, whereas crude protein, crude fiber, and ash contents were increased, but lowered the carbohydrate and calorie values**.** Quinoa is considered a wholegrain product, it is a valuable source of proteins, fat, minerals, vitamins, fiber, and other nutrients as stated by **Huang *et al.* (2024).**

Table (5): Proximal composition of the muffin of each treatment (individual and in combination) that achieved better characteristics (g/100g as it is) as (mean +SE).

Muffin	Moisture	Protein	Fat	Carbohydrate	Fiber	Ash
Control	$32.85^{ab}±1.15$	$10.77^{c}±0.35$	$26.48^{b}±0.47$	$26.82^{a}±0.44$	$1.25^{ab}±0.14$	$1.83^{b}±0.18$
5% SF	$31.82^{b}±1.12$	$14.65^{a}±0.40$	$28.91^{a}±0.48$	$20.56^{c}±0.43$	$1.31^{a}±0.13$	$2.75^{a}±0.20$
5% QF	$32.91^{ab}±1.14$	$12.38^{b}±0.39$	$28.21^{a}±0.43$	$23.37^{b}±0.46$	$1.12^{b}±0.11$	$2.01^{ab}±0.19$
1% CSP	$33.18^{a}±1.13$	$10.75^{c}±0.33$	$26.44^{b}±0.41$	$26.47^{a}±0.48$	$1.31^{a}±0.15$	$1.85^{b}±0.17$
5% SF + 5% QF	$33.41^{a}±1.16$	$10.72^{c}±0.31$	$26.40^{b}±0.47$	$26.27^{ab}±0.45$	$1.33^{a}±0.13$	$1.87^{b}±0.16$

SF: Soybean flour, QF: Quinoa flour, CSP: Carob seeds powder.
Values in the same column with various superscript letters are significantly different at ($P < 0.05$).

Minerals content of the muffin product of each treatment that achieved better characteristics (mg/kg) are presented in **Table (6).** Calcium contents (mg/kg) were found to be higher in (5%SF+5%QF) muffin as compared to that of the control muffin (348.82 and 332.82, respectively). Zinc content of control was higher than that of the other muffin samples (5%SF and 5%SF+5% QF). On the other hand, iron content of (5%SF+5%QF) barley muffin was found to be higher (40.09 mg/kg) than that of the control muffin, followed by 1%CSP barley muffin (24.00) and 5%SF barley muffin (20.65). Increasing in minerals content of these muffins samples could be due to the highest content of ash in soybean flour, followed by carob seeds powder as presented previously in (**Table 2**). According to other investigators (**Ghoshal and Kaushik, 2020)**, calcium and iron contents of soybean-fortified cookies were higher than the control (wheat flour) cookies. The addition of soy flour increased the levels of these minerals in the cookies. Also, **Goyat *et al.* (2018)** found that with increasing concentration of quinoa flour, iron and calcium content increased significantly. In addition, **Higazy *et al.* (2018**) established that carob is a good source of microelements, particularly calcium, and providing microelements (iron and zinc).

Table (6): Minerals content of the muffin products of each treatment that achieved better characteristics (mg/kg).

Muffin	Calcium	Zinc	Iron
Control	332.82	15.72	18.97
5% SF	270.35	13.08	20.65
5% QF	292.69	11.08	17.48
1% CSP	206.80	9.48	24.00
5% SF + 5% QF	348.82	12.25	40.09

SF: Soybean flour, QF: Quinoa flour, CSP: Carob seeds powder.

Barley muffin products stability under storage conditions:

Muffin products stability under storage conditions (25˚C for 7 days) of each treatment that achieved better characteristics are presented in **Table (7)**. The results showed that product stability was significantly ($P< 0.05$) high in muffin products with (5%SF+5%QF) and (1%CSP), followed by (5%SF) compared to the control and (5%QF) muffin throughout all storage periods under the present investigations. According to **Salehi (2019)** gums are usually added to minimize non-desired changes in crumb texture during storage. Also, **Nguyen *et al.* (2015)** stated that water holding capacity of soy protein is important as it affects the texture, juiciness, and taste of food formulations, and particularly the shelf-life of bakery products.

Table (7): Product stability of the muffin product of each treatment that achieved better characteristics upon storage (25˚C for 1 week) as (Mean ±SE).

Muffin	At zero time	On day 4	On day 7
Control	41.60^{d}±1.01	32.93^{e}±1.04	24.80^{e}±1.02
5% SF	46.46^{c}±1.02	38.13^{c}±1.14	34.26^{c}±1.11
5% QF	42.13^{d}±1.12	34.06^{d}±1.09	30.13^{d}±1.08
1% CSP	48.46^{b}±1.15	40.86^{b}±1.10	36.86^{b}±1.11
5% SF + 5% QF	51.33^{a}±1.12	43.80^{a}±1.14	39.93^{a}±1.13

SF: Soybean flour, QF: Quinoa flour, CSP: Carob seeds powder.
Values in the same column with various superscript letters are significantly different at ($P < 0.05$).

Conclusion

Based on the results of the present study, it can be concluded that soybean flour, quinoa flour, and carob seed powder can be used as functional ingredients to improve the physical characteristics, nutritional value (protein, fiber, calcium, iron), and storage stability of barley muffins when used at appropriate concentrations. Therefore, the study recommended that the bakery industry partially substitute barley flour during muffin preparation with 5% soybean flour, 5% quinoa flour, or 1% carob seed powder individually. These ingredients can also be used in combination (5% soybean flour and 5% quinoa flour) to enhance the quality and characteristics of barley muffins.

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تحسين جودة والقيمة الغذائية لمافن الشعير بإضافة مكونات وظيفية مختلفة

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الملخص العربي

يعد المافن من المنتجات المخبوزة الحلوة التي تحظى بتفضيل كبير من المستهلكين، نظرًا لقوامها الطري ومذاقها المميز. هدفت هذه الدراسة إلى تقييم تأثير استخدام مستويات مختلفة من مكونات وظيفية، وهي: دقيق الصويا(SF)، دقيق الكينوا(QF)، ومسحوق بذور الخروب(CSP)، بشكل فردي وفي صورة خليط، على جودة والقيمة الغذائية للمافن المصنوع من دقيق الشعير. أظهرت النتائج وجود زيادة معنوية ($P<0.05$) في قدرة الإمتصاص المائي عند إضافة 3% من مسحوق بذور الخروب مقارنة بالمعالجات الأخرى(10%SF) و(10%QF) والعينة الضابطة. كما أظهر المافن المحتوي على 10% دقيق الصويا زيادة معنوية ($P<0.05$) في الحجم مقارنة بالمعالجات الأخرى والعينة الضابطة. تحسنت درجة الطراوة بشكل ملحوظ مع المعالجات الفردية التي تضمنت 5% و10% من دقيق الصويا، 5% و10% من دقيق الكينوا، و1% و3% من مسحوق بذور الخروب. كما أدت الخلطات المكونة من (5%SF+1%CSP) و(5%SF+5%QF) إلى تحسين ملحوظ في درجة الطراوة مقارنة بالعينة الضابطة. أشارت نتائج التقييم الحسي إلى أن المافن المعالج بشكل فردي بنسبة (5%SF) أو(5%QF) أو(1%CSP) حصل على درجات تقييم حسي أعلى بشكل معنوي($P<0.05$). واحتفظ خليط (5%SF+5%QF) بدرجات قبول أعلى مقارنة بالمعالجات الأخرى، كما أظهر هذا الخليط محتوى أعلى من الكالسيوم والحديد مقارنة بالعينة الضابطة. علاوة على ذلك، حدث تحسن فى درجة ثبات المنتج بشكل ملحوظ خلال فترة التخزين عند درجة حرارة 25 °C لمدة 7 أيام عند معالجته بخليط من (5%SF+5%QF أو 1%CSP). توصى الدراسة بالاستبدال الجزئي لدقيق الشعير بنسبة 5% من دقيق الصويا أو دقيق الكينوا أو 1% من مسحوق بذور الخروب، سواء بشكل فردي أو في صورة خليط، يمكن أن يحسن من جودة ودرجة طراوة وثبات والقيمة الغذائية للمافن المصنوع من دقيق الشعير.

الكلمات المفتاحية: أغذية وظيفية، مافن، الشعير، فول الصويا، الكينوا، بذور الخروب.