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Effects of flaxseed on the nutritional and sensory qualities of pan and Arabic flat breads

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Abstract:
Flaxseed is a useful source of omega-3 fatty acid and many health-promoting phytochemicals. Baked products are extensively consumed in the Arabic countries. This study mainly aimed to improve the nutritional quality of pan and Arabic flat breads by adding whole and crushed flaxseed.
The study objects were pan and Arabic flat breads wholegrain and white wheat flour with whole or crushed flaxseed at different amounts. The proximate composition, texture, color characteristics, and sensory analysis were evaluated by standard methods.
The fat content increased in both the white wheat flour and in the wholegrain wheat flour pan breads with 8% of crushed flaxseed. The addition of 8% of crushed flaxseed to the white wheat flour bread also increased its specific loaf volume, while the addition of 8% of whole flaxseed significantly decreased the specific loaf volume of the wholegrain wheat flour bread. Crushed flaxseed did not affect the *L** values, but significantly increased the *a** values in the white wheat flour pan bread. Supplementing the white wheat flour pan bread with 8% of whole flaxseed decreased the compression force, thus indicating a softer texture. 8% of whole flaxseed significantly increased fat and protein contents of the white wheat and wholegrain wheat flour pan breads. Similar trends were observed for the Arabic breads, thus proving the enhancing effect of flaxseed on the nutritional quality of these baked products. The addition of crushed flaxseed to white wheat flour Arabic bread adversely affected its appearance and crust color, as well as significantly increased its ash, fat, protein, and dietary fiber contents. However, it did not have any adverse effect on the texture, flexibility, and flavor.
Flaxseed grains in the amount of 8% can be recommended to produce baked products with good sensory and nutritional qualities.

Keywords: Crushed and whole flaxseed, dietary fiber, Arabic bread, pan bread, nutritional quality

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INTRODUCTION

Eating right has been recommended to attain a relatively disease-free life. Nowadays, more and more consumers are interested in eating healthy foods not only for good taste or nutrition, but also to prevent noncommunicable diseases, such as type 2 diabetes, heart diseases, and several types of cancer [1–4]. Current nutrition research continues to identify various bioactive compounds in foods that appear to function as protectors against such diseases. In particular, consumers are advised to increase their intake of fiber-rich whole grains, plant fibers (psyllium), and flaxseed [5–7].

The flaxseed grain is a tiny, smooth, flat seed. Its color ranges from light red to reddish brown. Flaxseed has been consumed by people in many Asian countries for about 5000 years [8]. It has been shown to be a useful and powerful agent against fatty degeneration in cardiovascular diseases, cancer, and type 2 diabetes [4]. In addition to nutrition, flaxseed has a few technological benefits in producing superior quality processed food products [9, 10]. Oil and protein are flaxseed's major components. Flaxseed meal (after crushing) also contains non-starch polysaccharides (mucilage), cyanogenic glycosides (precursor of hydrocyanic acid and thiocyanate), phytic acid, phenolics, mammalian trypsin and chymotrypsin inhibitors, linatin (vitamin B_6 inhibitors), and lignans (diglucosides) with anti-neoplastic and anti-estrogenic properties [11].

About two-thirds of flaxseed fiber is water-insoluble and consists of non-starch polysaccharides, such as cellulose and lignin [12]. Insoluble fiber helps improve laxation and prevent constipation, mainly by increasing fecal bulk and reducing bowel transit time [13]. A water-soluble fiber fraction of flaxseed comprises about one-third of total dietary fiber. There has been research into the heterogeneous nature of a purified water-soluble neutral fraction coming from the mucilage gum of flaxseed. Water-soluble fiber helps maintain blood glucose levels and lowers blood cholesterol levels [4, 12]. High-fiber foods are also reported to offer protection against certain types of cancer [14]. A high-fiber diet helps lower blood levels of lipids and certain hormones [7]. A low-fiber, high-fat diet tends to raise blood estrogen levels, which may contribute to cancer development by stimulating tumor cell growth [15, 16].

Food processors have always attempted to incorporate newer healthy ingredients to produce a variety of health-promoting functional foods. Flaxseed is one of such promising functional ingredients that can be used in baked goods and other cereal-based products. There is a strong rationale for introducing this ingredient into our staple foods, such as Arabic flat and pan breads, to provide a safety net for those at a higher risk of noncommunicable diseases. As humans now live longer, they can benefit from consuming grains (such as flaxseed) rich in health-promoting bioactive compounds. Therefore, we aimed to study the benefits of flaxseed for enhancing the nutritional quality of Arabic flat and pan breads, which are now commonly consumed all over the world.

STUDY OBJECTS AND METHODS

Raw materials. Wholegrain wheat flour and white wheat flour samples were obtained from the Kuwait Flour Mills & Bakeries Co., Shuwaikh. Fine granulated sugar, common salt, bakery shortening (Wesson, USA), whole flaxseed, instant dry yeast, non-fat dry milk, and baking supplies were procured from the local market. The diacetyl tartaric acid ester of mono- and diglycerides was a free gift from the American Ingredients Company (Kansas City, Missouri, USA).

Optimization of pan bread formulation. The optimized straight dough bread making method (AACC method 10-10-B) was used for baking trials with a few modifications as reported earlier [6]. Every bake was repeated 3 to 4 times, with and without whole and crushed flaxseed, and the averages of two best bakes were tabulated. Wholegrain and white wheat flours were replaced with 2, 4, 6, and 8% of flaxseed for producing pan breads. The amounts of flour and flaxseed were based on the 14% moisture. After preliminary trials, the use of 4 and 8% of flaxseed with 0.5% of diacetyl tartaric acid ester of mono- and diglycerides was optimized for these bread formulations. Water absorption was optimized by adding as much water as possible while keeping the dough still manageable to handle and the water required was calculated as baking absorption percentage. The bread samples, immediately taken out of the oven, were weighed, and loaf volume was measured by the rapeseed displacement method as reported earlier [6].

Optimization of Arabic bread formulation. For Arabic bread making, wholegrain and white wheat flour were used as controls, with varying levels of flaxseed (whole or crushed). Arabic breads were made according to the method reported earlier [17]. The wholegrain and white wheat flour were replaced with 2, 4, 6, and 8% of flaxseed. The amounts of flour and flaxseed for these trials were based on the 14% moisture. After preliminary trials, the use of 4 and 8% of flaxseed with 0.5% of diacetyl tartaric acid ester of mono- and diglycerides was optimized, and the prepared Arabic bread samples were used for further analyses.

Chemical analyses. The pan and Arabic bread samples were freeze-dried and powdered in a Falling Number Mill (Model 3100, Sweden) to pass through a 100-mesh sieve. They were stored in airtight containers in a refrigerator (4°C) until further chemical analysis.

All the bread samples were analyzed for proximate composition, such as moisture (Method 44-19), crude protein (Method 46-12), total ash (Method 08-01), and crude lipids (Method 30-25) by using the standard AACC methods as reported earlier [6]. The results were expressed on a moisture-free basis. The nitrogen content determined by the Kjedalhl method was converted into a crude protein content using a conversion factor of N×5.70 for bread samples. All the analyses were conducted in triplicate, with the averages presented here. The pan and Arabic bread samples were also analyzed for insoluble, soluble, and total dietary fiber contents according to the standard AACC methods as reported earlier [17].

Instrumental texture measurement. After baking, the pan bread samples were cooled for about 2 h to reach the room temperature of 22 ± 1°C. From the middle portion of each bread sample, four slices of uniform thickness (2.5 cm) were obtained and immediately taken for objective texture measurement. The texture was measured using a Stable Micro Systems TAXT2 texture analyzer (UK) with a plastic plunger (2.5 cm diameter, 1.7 mm/s speed, peak compression force at 30% compression, 7.5 mm compression depth). The peak compression force was measured in the center of all the four slices, and the mean ± S.D. values were reported [18].

Objective color measurements. The crumb color of the pan bread samples cooled to room temperature (22 ± 1°C) was measured with a Model 545 Macbeth Color Checker, a potable spectrophotometer (Kollmorgen Instruments Corp., UK) as CIE L^* a^* b^* values. Under this tristimulus color coordinate system, the L^* value (lightness) varies from 0 (black) to 100 (white), the a^* value (redness) varies from –100 (green) to +100 (red), and the b^* value (yellowness) varies from –100 (blue) to +100 (yellow). As the values of a^* and b^* rise, the color becomes more saturated or chromatic, but these values approach zero for neutral colors (white, grey, or black). The instrument settings were illuminant D_{50}, display L^* a^* b^*, and the observer angle of 2°. The instrument was calibrated with a white primary tile supplied by the manufacturer. After slicing the bread loaf into two halves, twelve readings were taken in the crumb area of both halves [19]. After discarding two most extreme readings, the remaining ten readings were averaged and reported along with their standard deviations.

Sensory analysis. The baked pan bread samples were cooled to room temperature (22 ± 1°C) and subjected to sensory analysis on the nine-point hedonic scale for crumb color, texture, flavor, and overall acceptability. A semi-trained panel consisted of 12 judges from the employees of the Kuwait Institute for Scientific Research, who gave their written informed consent [17]. Each panelist was served with a control sample along with the test samples and was asked to assign scores. A sensory score of 5 or above was rated as acceptable, and a score below 5 was considered unacceptable. The data were subjected to analysis of variance, and the average values were reported.

Statistical analysis. All of the chemical analyses were reported on a moisture-free basis. The data were subjected to analysis of variance, and the mean values were evaluated for statistical significance (p = 0.05) using the Duncan's New Multiple Range Test (SAS Program, Windows Version 6.08, ANOVA Procedure), with inferences reported at the appropriate places [6].

RESULTS AND DISCUSSION

Chemical analyses. As evident from the data in Table 1, the chemical composition of pan bread was affected by the addition of whole flaxseed to the control with white wheat flour. With 8% of flaxseed added to the white wheat flour control bread, the fat and protein contents increased from 2.72 to 6.01%, and from 13.32 to 14.11%, respectively. Similar trends in fat and protein contents were also observed with the addition of crushed flaxseed to the white wheat flour sample. With 8% of whole flaxseed added to the wholegrain wheat flour control, the fat content increased from 3.67 to 6.32% in the test samples (Table 2). A similar trend in the fat content was observed in the wholegrain wheat flour pan bread with 8% of crushed flaxseed. However, the protein content of the wholegrain wheat flour sample did not show any significant differences with the addition of 8% of crushed or whole flaxseed. Also, the ash content was not affected significantly in either the white or the wholegrain wheat flour pan breads with 8% of crushed or whole flaxseed.

Specific loaf volume and instrumental texture. Pan bread is valued not only for its loaf volume, flavor, or nutritional quality but also for its desirable physical texture. Bakers have always attempted to improve the specific loaf volume, physical texture, and shelf life of pan bread using various additives, such as dough improvers or bread softeners [18]. The pan bread loaf volume as affected by the addition of crushed or whole flaxseed was measured in terms of cc/g (Table 3). The addition of 8% of crushed or whole flaxseed to the white wheat flour control pan bread significantly increased the specific loaf volume from 4.11 to 4.51 cc/g and from 4.02 to 5.09 cc/g in the test samples, respectively. As for the wholegrain wheat flour control pan bread, crushed flaxseed did not significantly change the specific loaf

Table 1 Effect of flaxseed addition on the chemical composition* of pan bread from white wheat flour, % dry basis

Sample	Ash	Fat	Protein
White wheat flour (control)	$2.13^a \pm 0.02$	$2.72^a \pm 0.01$	$13.32^a \pm 0.34$
White wheat flour + 4% Crushed flaxseed	$2.45^a \pm 0.02$	$4.54^b \pm 0.01$	$13.85^b \pm 0.05$
White wheat flour + 8% Crushed flaxseed	$2.53^a \pm 0.05$	$5.63^c \pm 0.03$	$14.07^b \pm 0.05$
White wheat flour + 4% Whole flaxseed	$2.07^a \pm 0.08$	$4.18^b \pm 0.05$	$13.77^a \pm 0.18$
White wheat flour + 8% Whole flaxseed	$2.11^a \pm 0.08$	$6.04^c \pm 0.03$	$14.11^b \pm 0.08$

Values with different superscripts differ significantly in a column (p = 0.05)

*Mean ± S.D.

Table 2 Effect of flaxseed addition on the chemical composition* of pan bread from wholegrain wheat flour, % dry basis

Sample	Ash	Fat	Protein
Wholegrain wheat flour (control)	$2.84^a \pm 0.04$	$3.67^a \pm 0.01$	$12.96^a \pm 0.09$
Wholegrain wheat flour + 4% Crushed flaxseed	$2.85^a \pm 0.15$	$5.34^b \pm 0.01$	$13.06^a \pm 0.02$
Wholegrain wheat flour + 8% Crushed flaxseed	$3.01^a \pm 0.08$	$6.58^c \pm 0.02$	$13.03^a \pm 0.25$
Wholegrain wheat flour + 4% Whole flaxseed	$2.84^a \pm 0.09$	$4.92^b \pm 0.03$	$13.14^a \pm 0.06$
Wholegrain wheat flour + 8% Whole flaxseed	$2.76^a \pm 0.23$	$6.32^c \pm 0.01$	$13.27^a \pm 0.17$

Values with different superscripts differ significantly in a column (p = 0.05)

*Mean ± S.D.

Table 3 Effect of flaxseed addition on the specific loaf volume of pan bread

Sample	Specific loaf volume, cc/g*	
	Crushed flaxseed	Whole flaxseed
White wheat flour (control)	$4.11^{a} \pm 0.21$	$4.02^{a} \pm 0.18$
White wheat flour + 4% flaxseed	$4.36^{b} \pm 0.12$	$4.66^{b} \pm 0.22$
White wheat flour + 8% flaxseed	$4.51^{c} \pm 0.12$	$5.09^{c} \pm 0.16$
Wholegrain wheat flour (control)	$3.64^{d} \pm 0.11$	$3.83^{d} \pm 0.14$
Wholegrain wheat flour + 4% flaxseed	$3.49^{d} \pm 0.22$	$3.93^{d} \pm 0.04$
Wholegrain wheat flour + 8% flaxseed	$3.56^{d} \pm 0.11$	$3.59^{e} \pm 0.23$

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

*Mean ± S.D.

Table 4 Effect of whole or crushed flaxseed addition on the objective texture of pan bread

Sample	Compression force, g*	
	Crushed flaxseed	Whole flaxseed
White wheat flour (control)	$368.4^{a} \pm 47.9$	$246.4^{a} \pm 29.3$
White wheat flour + 4% flaxseed	$371.0^{a} \pm 48.7$	$200.5^{b} \pm 34.0$
White wheat flour + 8% flaxseed	$365.4^{a} \pm 34.6$	$197.7^{b} \pm 26.0$
Wholegrain wheat flour (control)	$366.3^{b} \pm 47.2$	$373.6^{d} \pm 45.2$
Wholegrain wheat flour + 4% flaxseed	$375.7^{b} \pm 56.1$	$412.9^{d} \pm 55.0$
Wholegrain wheat flour + 8% flaxseed	$306.8^{c} \pm 53.4$	$459.8^{e} \pm 46.0$

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

*Mean ± S.D.

Table 5 Objective color measurements** of pan breads with crushed flaxseed

Sample	*L**	*a**	*b**
White wheat flour (control)	$65.5^{a} \pm 1.7$	$-0.80^{a} \pm 0.30$	$13.5^{a} \pm 1.0$
White wheat flour + 4% crushed flaxseed	$62.6^{b} \pm 1.6$	$0.37^{b} \pm 0.20$	$13.1^{a} \pm 0.8$
White wheat flour + 8% crushed flaxseed	$59.9^{c} \pm 1.4$	$0.94^{c} \pm 0.40$	$13.0^{a} \pm 0.9$
Wholegrain wheat flour (control)	$60.5^{d} \pm 1.6$	$3.58^{d} \pm 0.50$	$21.9^{b} \pm 1.1$
Wholegrain wheat flour + 4% crushed flaxseed	$59.6^{e} \pm 1.8$	$4.53^{e} \pm 0.40$	$22.4^{b} \pm 0.8$
Wholegrain wheat flour + 8% crushed flaxseed	$56.2^{f} \pm 1.2$	$4.69^{e} \pm 0.30$	$21.2^{b} \pm 0.8$

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

**Mean ± S.D.

volume of the test samples, while whole flaxseed decreased the specific loaf volume of the wholegrain wheat flour bread.

The instrumental texture of the pan breads supplemented with crushed or whole flaxseed was measured as compression force values (Table 4). As can be seen, the texture was not significantly affected by the addition of crushed flaxseed to the white wheat flour bread samples. However, in case of the wholegrain wheat flour control pan bread (366.2 g), the sample with 8% of crushed flaxseed had a significantly softer texture (306.8 g). The texture of the control white wheat flour bread was harder (246.4 g) than that of the sample with 8% of whole flaxseed (197.7 g). Similar texture softening of the bread supplemented with soluble dietary fiber was reported earlier [18]. However, the wholegrain wheat flour pan bread made with 8% of whole flaxseed had a significantly harder texture (459.8 g) than the control wholegrain wheat flour pan bread (373.6 g).

Objective color measurements of pan bread crumb. The objective color of pan bread crumb affected by the addition of flaxseed was measured in terms of CIE *L** *a** *b** tristimulus values using the procedure reported earlier [19]. The results for crushed and whole flaxseed are presented in Tables 5 and 6, respectively. The white wheat flour and wholegrain wheat flour control pan breads made with 8% of crushed flaxseed had their lightness values decreasing from 65.5 to 59.9 and from 60.5 to 56.2, respectively. This indicated that the crumb color became significantly darker. Furthermore, it was darker in the wholegrain wheat flour bread than in the white wheat flour bread (Table 5). There were insignificant changes in the *b** values for both the white and wholegrain wheat flour breads with the addition of crushed flaxseed. However, there was a significant change in the *a** values for the control white wheat flour bread (–0.80) compared to the sample supplemented with 8% of crushed flaxseed (0.94).

Table 6 Objective color measurements** of pan breads with whole flaxseed

Sample	L^*	a^*	b^*
White wheat flour (control)	66.3^a ± 1.8	–0.86^a ± 0.10	13.7^a ± 1.1
White wheat flour + 4% whole flaxseed	64.2^b ± 1.4	–0.84^a ± 0.20	12.0^b ± 0.6
White wheat flour + 8% whole flaxseed	63.4^b ± 2.0	–0.71^a ± 0.30	11.4^c ± 0.8
Wholegrain wheat flour (control)	61.2^d ± 1.4	3.90^b ± 0.40	23.1^d ± 1.1
Wholegrain wheat flour + 4% whole flaxseed	61.3^d ± 1.2	3.70^b ± 0.50	21.9^e ± 1.1
Wholegrain wheat flour + 8% whole flaxseed	62.1^e ± 2.1	3.80^b ± 0.30	22.1^e ± 0.8

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

**Mean ± S.D.

Table 7 Sensory quality scores* for Arabic breads with crushed flaxseed

Sample Code	Appearance	Crust color	Texture	Flexibility	Flavor
White wheat flour (control)	7.8^a ± 0.9	7.8^a ± 0.7	6.9^a ± 1.1	7.5^a ± 0.9	7.0^a ± 1.2
White wheat flour + 4% crushed flaxseed	7.1$^{b\text{-}a}$ ± 0.9	7.0^{ab} ± 1.0	6.9^a ± 0.8	6.5^a ± 1.0	6.8^a ± 0.6
White wheat flour + 8% crushed flaxseed	6.6^b ± 1.3	6.6^b ± 0.9	7.1^a ± 1.1	6.9^a ± 1.2	7.0^a ± 0.9
Wholegrain wheat flour (control)	7.8^d ± 0.4	7.2^c ± 0.6	7.3^b ± 0.9	7.1^b ± 0.5	7.0^b ± 0.6
Wholegrain wheat flour + 4% crushed flaxseed	7.6^{de} ± 1.1	7.3^c ± 1.2	7.1^b ± 1.1	7.5^b ± 0.8	7.1^b ± 0.9
Wholegrain wheat flour + 8% crushed flaxseed	6.8^e ± 1.1	6.6^{cd} ± 1.1	7.1^b ± 1.3	7.1^b ± 1.2	7.0^b ± 1.1

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

**Mean ± S.D.

Table 8 Sensory quality scores* for Arabic breads with whole flaxseed

Sample Code	Appearance	Crust color	Texture	Flexibility	Flavor
White wheat flour (control)	7.4^a ± 0.9	6.8^a ± 0.9	6.9^a ± 0.9	7.2^a ± 1.1	7.5^a ± 0.9
White wheat flour + 4% whole flaxseed	7.4^a ± 0.5	7.1^a ± 0.7	7.4^a ± 0.7	7.9^a ± 0.7	7.6^a ± 0.8
White wheat flour + 8% whole flaxseed	7.2^a ± 0.8	6.9^a ± 1.2	7.0^a ± 1.1	7.0^a ± 1.1	7.8^a ± 1.0
Wholegrain wheat flour (control)	7.4^b ± 1.1	7.2^b ± 0.8	6.4^b ± 0.8	6.2^b ± 1.2	6.7^c ± 0.9
Wholegrain wheat flour + 4% whole flaxseed	7.7^b ± 0.7	7.6^b ± 0.8	7.3^c ± 0.9	7.3^c ± 0.7	7.8^d ± 0.6
Wholegrain wheat flour + 8% whole flaxseed	7.7^b ± 0.7	7.9^b ± 0.7	8.2^d ± 0.4	8.1^c ± 0.7	7.8^d ± 0.6

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

**Mean ± S.D.

This indicated that crushed flaxseed made the red color of the white wheat flour crumb significantly darker.

The effects of adding whole flaxseed to the white and wholegrain wheat flour breads on their crumb color are shown in Table 6. As can be seen, the L^* values for the white wheat flour control bread crumb (66.3) significantly decreased to 63.4 with the addition of whole flaxseed, which made it appear darker. On the other hand, the addition of whole flaxseed to the wholegrain wheat flour control bread significantly increased its crumb color L^* values from 61.2 to 62.1, making it appear lighter, probably due to the dilution effect on the wheat bran [1].

Sensory quality of pan and Arabic bread. All the Arabic bread samples made with crushed flaxseed were evaluated for various sensory attributes, such as appearance, crust color, texture, flexibility, and flavor on the 9-point hedonic scale using semi-trained panelists (Table 7). The panelists did not find any significant differences in texture, flexibility, and flavor between the white and wholegrain wheat flour Arabic control breads and those made with 8% of crushed flaxseed. However, the panelists gave slightly but significantly lower sensory scores for the appearance and crust color of the samples containing crushed flaxseed compared to the control. Interestingly, the panelists could not find any significant differences in appearance, crust color, texture, flexibility, and flavor between the white wheat flour control samples and those made with 8% of whole flaxseed (Table 8). Furthermore, they gave consistently higher sensory scores for all the attributes of the samples with whole flaxseed, compared to the control. Thus, if consumers make this Arabic bread part of their usual diet, they could increase their dietary fiber intake [20, 21].

All the white and wholegrain wheat flour pan breads made with crushed or whole flaxseed were evaluated for color, texture, flavor, and overall acceptability on the 9-point hedonic scale by semi-trained panelists (Tables 9 and 10).

Dietary fiber contents. Flaxseed is a useful source of dietary fiber that provides about 28 g of total dietary fiber/100 g on a dry weight basis. About two-thirds of flaxseed dietary fiber is water-insoluble and the remaining one-third is water-soluble [11, 12]. The dietary fiber contents in the pan and Arabic breads made from white and wholegrain wheat flour with various amounts of crushed or whole flaxseed are presented in Figs. 1 to 9. We found a significant increase in dietary fiber with 8% of flaxseed in both the pan and Arabic bread samples (Figs. 1–9). The white wheat flour Arabic breads with crushed or whole flaxseed had higher insoluble dietary fiber contents compared to that of the control (Figs. 5 and 7).

The major components of flaxseed are oil and protein. Flaxseed meal (after crushing) also contains non-starch polysaccharides (mucilage), cyanogenic glycosides (precursor of hydrocyanic acid and thiocyanate), phytic acid, phenolics, mammalian trypsin and chymotrypsin inhibitors, linatin (vitamin B_6 inhibitors), and lignans (diglucosides) with anti-neoplastic and anti-estrogenic properties [22, 23]. Flaxseed is also rich in unsaturated fats that are useful in improving the nutritional quality of pan bread made with this ingredient [4].

Nutrition and health professionals recommend including more plant-based foods in our diets. Since flaxseed is mainly rich in superior quality fat and proteins, its incorporation into wheat flour can produce highly nutritious baked goods. Compared to our results, Daun and DeCrecq, who studied Canadian flaxseed, reported significantly higher contents of fat (41%), protein (20%), total dietary fiber (28%), moisture (7.7%), and total ash (3.4%) [24]. In another study of white wheat flour panbread supplemented with crushed flaxseed, 5%

Table 9 Sensory quality scores* for pan bread with added crushed flaxseed

Sample Code	Color	Texture	Flavor	Overall acceptability
White wheat flour (control)	$7.6^a \pm 0.7$	$7.4^a \pm 0.7$	$6.9^a \pm 0.7$	$7.1^a \pm 0.5$
White wheat flour + 4% crushed flaxseed	$7.2^a \pm 0.6$	$7.1^a \pm 0.8$	$7.3^a \pm 0.6$	$7.2^a \pm 0.6$
White wheat flour + 8% crushed flaxseed	$6.9^a \pm 0.7$	$7.1^a \pm 0.9$	$7.4^a \pm 0.6$	$7.2^a \pm 0.6$
Wholegrain wheat flour (control)	$7.2^b \pm 1.2$	$7.2^b \pm 0.6$	$7.2^b \pm 0.8$	$7.2^b \pm 0.7$
Wholegrain wheat flour + 4% crushed flaxseed	$6.8^b \pm 0.6$	$6.7^b \pm 0.8$	$6.7^b \pm 0.6$	$6.6^b \pm 0.8$
Wholegrain wheat flour + 8% crushed flaxseed	$6.6^b \pm 0.8$	$6.5^b \pm 0.7$	$6.6^b \pm 0.6$	$6.5^b \pm 0.8$

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

**Mean ± S.D.

Table 10 Sensory quality scores* for pan bread with added whole flaxseed

Sample Code	Color	Texture	Flavor	Overall acceptability
White wheat flour (control)	$7.1^a \pm 0.8$	$7.1^a \pm 1.2$	$6.4^a \pm 1.2$	$6.8^a \pm 1.0$
White wheat flour + 4% whole flaxseed	$7.2^a \pm 0.6$	$6.9^a \pm 1.3$	$7.4^a \pm 0.8$	$7.2^a \pm 0.7$
White wheat flour + 8% whole flaxseed	$7.1^a \pm 0.8$	$6.8^a \pm 1.7$	$7.2^a \pm 1.2$	$7.2^a \pm 0.7$
Wholegrain wheat flour (control)	$6.7^b \pm 1.3$	$6.6^b \pm 1.4$	$6.6^b \pm 1.6$	$6.9^b \pm 1.1$
Wholegrain wheat flour + 4% whole flaxseed	$6.7^b \pm 1.0$	$6.4^b \pm 1.1$	$7.0^b \pm 1.1$	$6.8^b \pm 1.1$
Wholegrain wheat flour + 8% whole flaxseed	$6.3^b \pm 1.3$	$6.7^b \pm 1.2$	$7.2^b \pm 0.9$	$6.6^b \pm 1.4$

Values with different superscripts for white or wholegrain wheat flour differ significantly in a column ($p = 0.05$)

**Mean ± S.D.

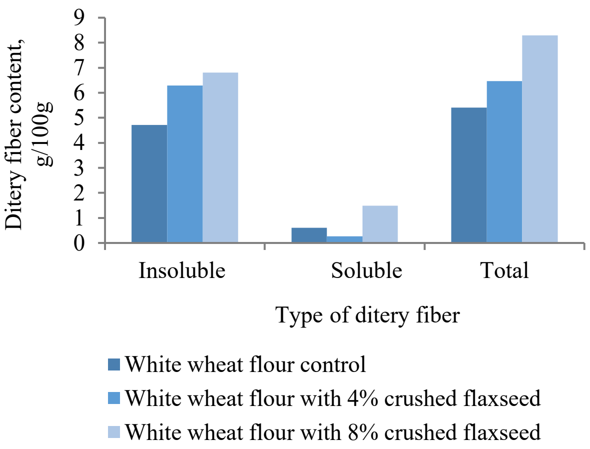

Figure 1 Dietary fiber in white wheat flour pan bread with crushed flaxseed

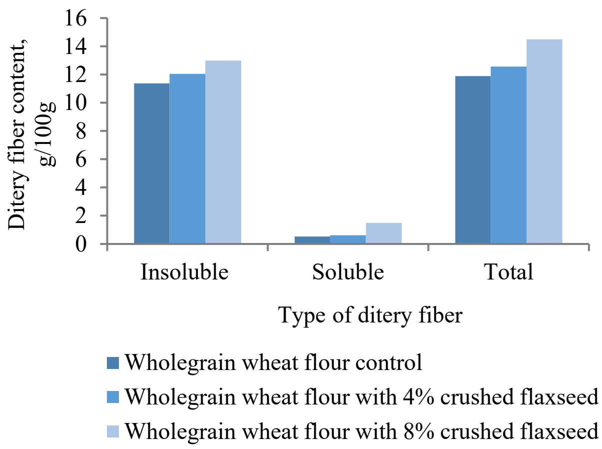

Figure 2 Dietary fiber in wholegrain wheat flour pan bread with crushed flaxseed

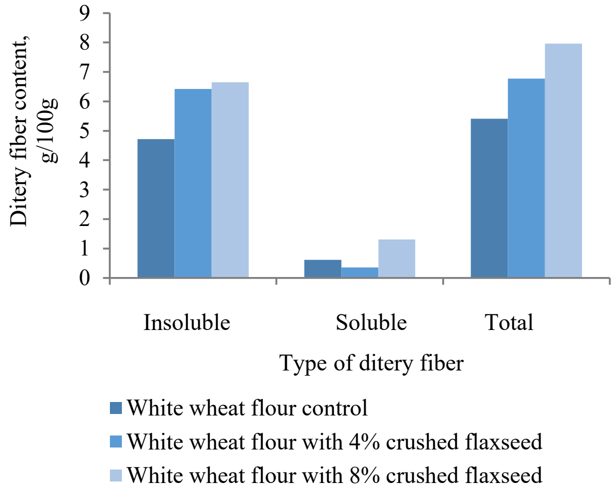

Figure 3 Dietary fiber in white wheat flour pan bread with whole flaxseed

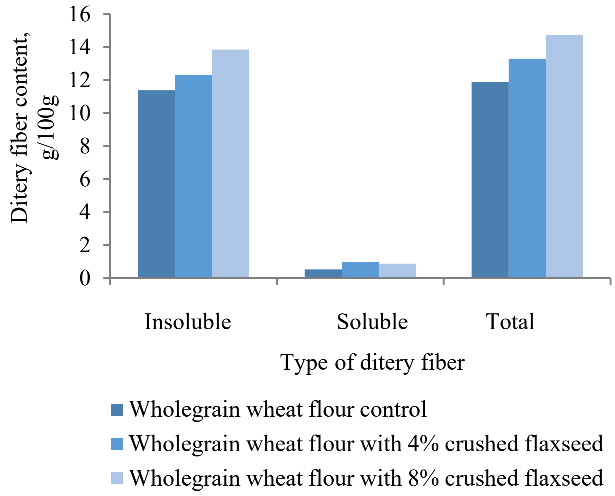

Figure 4 Dietary fiber in wholegrain wheat flour pan bread with whole flaxseed

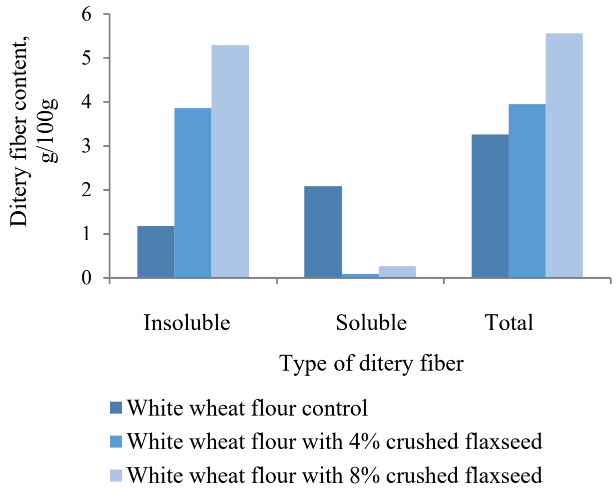

Figure 5 Dietary fiber in white wheat flour Arabic bread with crushed flaxseed

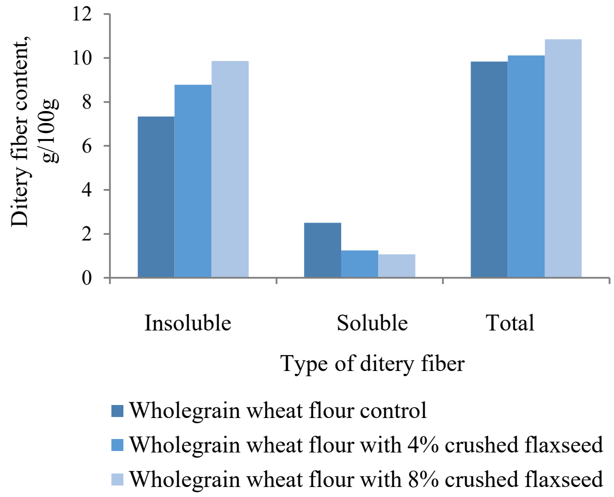

Figure 6 Dietary fiber in wholegrain wheat flour Arabic bread with crushed flaxseed

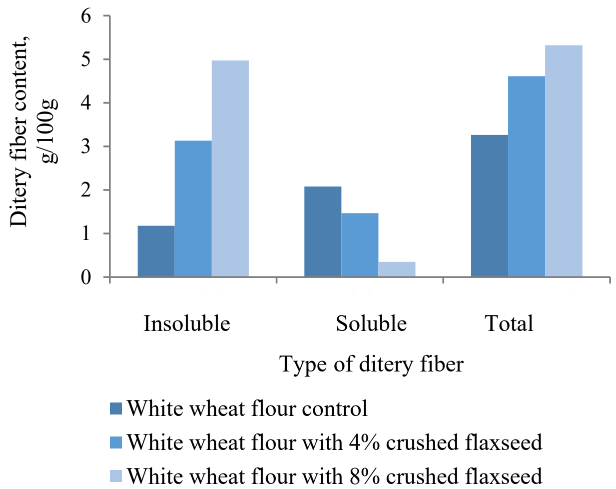

Figure 7 Dietary fiber in white wheat flour Arabic bread with whole flaxseed

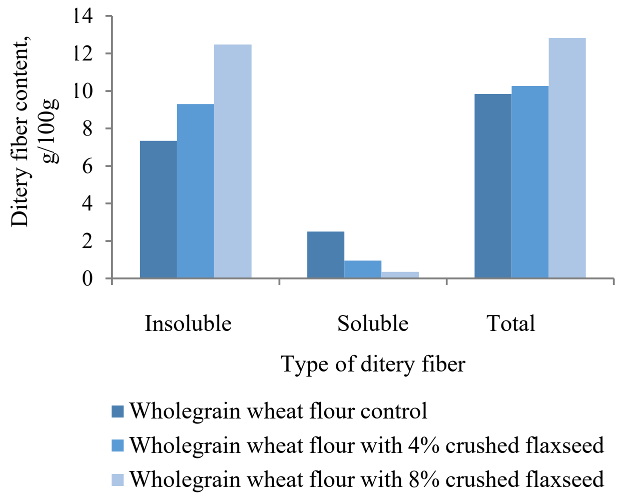

Figure 8 Dietary fiber in wholegrain wheat flour Arabic bread with whole flaxseed

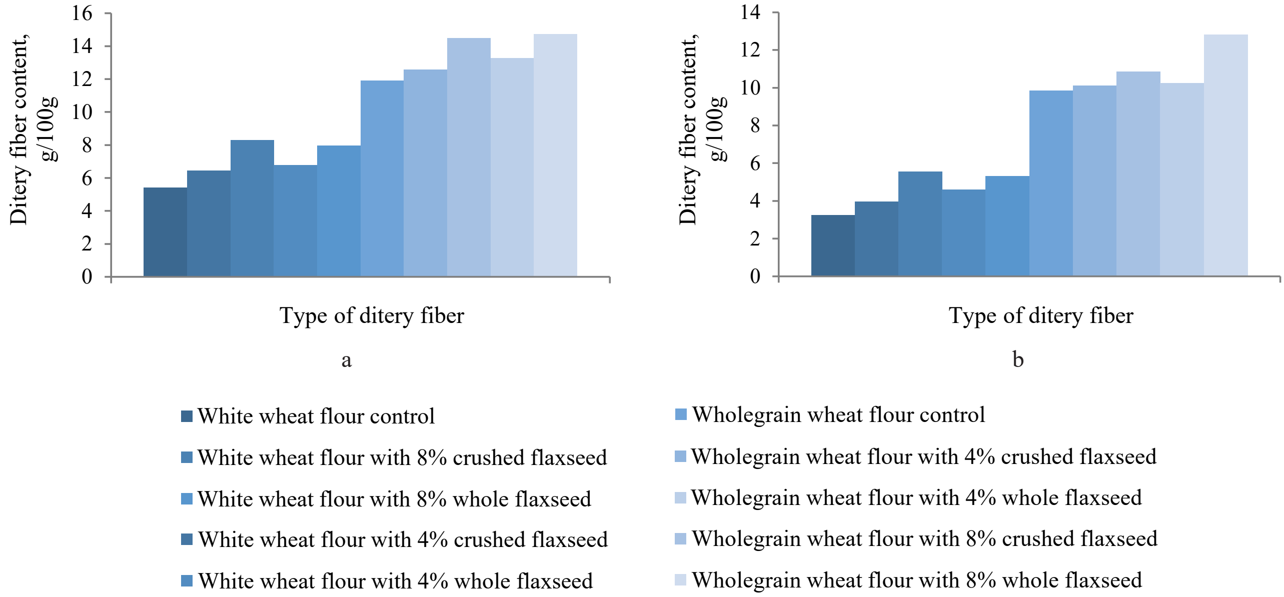

Figure 9 The total dietary fiber content in white and wholegrain wheat flour pan bread (a) and Arabic bread (b) with whole or crushed flaxseed

of flaxseed produced ash and fat contents similar to our results, but at 10% of flaxseed, the contents of ash, fat, and protein were significantly higher than in our study [25].

The addition of whole or crushed flaxseed decreased the specific loaf volume of pan bread, especially in the samples made from wholegrain wheat flour. This might be due to the dilution of gluten proteins, as well as the rupture of gas cell walls by whole flaxseeds [26, 27]. The change in specific loaf volume also significantly affected the instrumental texture of pan bread. The harder texture of the wholegrain wheat flour pan bread with 8% of flaxseed can be explained by the compact structure of this bread, mainly because of its lower specific loaf volume (Table 3). The addition of crushed or whole flaxseed (10%) has also been reported to reduce the specific loaf volume of control pan bread from 2.68 to 2.42 cc/g [25]. This decrease has been attributed to the dilution of gluten proteins and the interference of lignans and dietary fiber components in the development of gluten network [28].

The flaxseed grain coat, because of its natural yellowish brown color, was expected to affect the crumb color of pan bread. The wholegrain wheat flour control bread notably changed its crumb color with the addition of crushed flaxseed (8%), with the a* value increasing from 3.58 to 4.69, indicative of a redder color. Interestingly, whole flaxseed did not produce significant differences in the a* values of either wholegrain or white wheat flour pan breads. However, the b* values of the white wheat flour bread significantly decreased from 13.7 for the control to 11.4 for the sample supplemented with whole flaxseed (8%), indicating a less chromatic or less saturated color. Similarly, the b* values for the wholegrain wheat flour bread significantly decreased from 23.1 for the control to 22.1 for the test sample with whole flaxseed. This was possibly due to the dilution effect on the bran in wholegrain wheat flour or the yellowish brown color of the whole flaxseed cell coat. Similar effects on the objective color of white and wholegrain wheat breads were reported earlier by Marpalle *et al.* [25]. According to their study, the crumb color became darker as the level of flaxseed increased from 0 (control) to 5 and 10%, with the a* values increasing (redder color) and the b* values decreasing (less chromatic or less saturated color). The addition of ground flaxseed was also shown to significantly affect the crumb and crust color of bread, making it darker, possibly due to the Maillard reaction of proteins and phenolic compounds in flaxseed [29].

One of the most important signs of success for any new food product is its acceptance by the ultimate consumers. In our study, the panelists could not find any significant differences in the sensory attributes among the control pan bread and the samples containing 8% of crushed or whole flaxseed, rating all the samples as well-accepted (a score of 5 and above). Interestingly, the panelists could not find any significant differences in the appearance, crust color, flexibility, texture, or flavor between the control Arabic bread and the samples made with 8% of whole flaxseed, finding all of them acceptable.

In the study by Marpalle *et al.*, 10% of roasted crushed flaxseed was also reported to produce acceptable breads, both from white and wholegrain wheat flour [25]. Our results were also consistent with those reported by Ramcharitar *et al.*, who used 11.6% of crushed flaxseed in muffins [30]. Of all the Arabic bread samples, the highest insoluble fiber content was found in the wholegrain wheat flour bread with 8% of whole flaxseed. Thus, supplementing white or wholegrain wheat flour breads with 8% of crushed or whole flaxseed significantly enhanced their total dietary fiber contents, which would definitely provide health benefits to the consumers.

In a recent study by Hussain *et al.*, 12% of full fat flaxseed and 16% of partially defatted flaxseed have been shown to enhance the dietary fiber content of pan bread and unleavened flat bread from 3.40 to 6.58% and from 12.64 to 17.45%, respectively [31]. The total dietary fiber contents in their study were much higher than in our work, possibly due to larger amounts of flaxseed used by them.

CONCLUSION

Flaxseed, a grain of immense nutritional value, has been utilized to produce pan bread as well as Arabic bread. Our results clearly indicate that staple baked products with good sensory and nutritional qualities can be produced using up to 8% of either crushed or whole flaxseed. Although the addition of crushed flaxseed had a slightly negative effect on the appearance and crust color of Arabic bread, it did not adversely affect its texture, flexibility, or flavor attributes. Interestingly, whole flaxseed is a better possibility since it did not adversely affect any of the sensory qualities, significantly enhancing the dietary fiber content in the bread. Thus, using flaxseed grains can be recommended to produce nutritionally superior baked products rich in dietary fiber for the benefit of the consumers.

CONTRIBUTION

All the authors contributed to this research. Ms. Jameela conceived the research idea, guided the research team, and conducted the objective color measurement. Dr. Fatima wrote the first draft of the manuscript, as well as prepared the tables and figures. Mr. Mohammad conducted the baking studies, texture measurement, and the chemical analyses. Ms. Amani conducted the statistical analyses of research data. Dr. Jiwan guided the research team and refined the last version of the manuscript. All the authors read and approved the final manuscript for submission to this journal.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest with regard to this research work.

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