The Effect of Adding Flaxseed Flour Powder on the Rheological Properties of Wheat Flour Powder in Bread Manufacturing

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Abstract

Integrating flaxseed into foodstuffs such as wheat flour and loaf bread is attempted to increase the dietary quality of the bread as it contains high amount of omega-3 fatty acids, dietary fibers and lignans that promote the health effects of flaxseed. This study aimed to investigate the rheological characteristics of wheat flour powder and loaf bread quality after incorporating flaxseed flour. The fine flaxseed flour was directly incorporated into wheat flour to a substitution level of 5%, 10%, and 15%, respectively. Then, mixed well, the proper amount of water was added, kneaded into dough, rested until fermented/proofed and finally baked into a loaf of bread. After that, the loaf bread quality (volume and weight) was determined, followed by rheological properties through different Brabender devices such as Farinograph (to determine water absorption, stability, development time, degree of softening at 10 minutes) and Amylograph (the activity of amylase enzyme) together with bread chemical composition (moisture, proteins, lipids, and ashes). Consequently, sensory characteristics (acceptability, taste, appearance, aroma, crust color, and texture) were determined with total phenolic and flavonoids. The results showed that adding various concentrations of flaxseed flour powder significantly ($p \leq 0.05$) increased Farinograph values such as flour powder water absorption, stability, and development time, while decreasing the degree of softening at 10 minutes, especially highest concentration (15%). The wheat flour samples in which flaxseed was incorporated had no amylase activity with a higher temperature at peak viscosity and lower gelatinization temperature than control samples. The loaf bread's physical and sensory quality improved after adding flaxseed flour at different concentrations. Additionally, adding different concentrations flaxseed flour into the bread flour enhanced flavonoid and phenolic contents. It was concluded from this study that incorporating different concentrations of flaxseed flour improved the rheological properties of wheat flour power and loaf bread quality, which might enhance their health quality for human use.

Keywords: Flaxseed, Farinograph, Amylograph, wheat flour, loaf bread

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Introduction

Bakery foodstuffs are prevalently consumed foods in the world that have a high vigor source as they are rich in nutrition due to their high quantity of fibers, carbohydrates, sugar, milk, oil/shortening, and some minor ingredients (baking soda, salt, yeast, flavoring, etc.) [1.[

Consumers interested in healthy diets in recent years; thus, some ingredients with biomedicinal properties that increase the bakery products' nutritional quality and palatability, reduce caloricity, as well as promote human health can be added in a whole or in a ground form into the bakery products that are rich in omega-3 fatty acids, essential amino acids, dietary fibers, with minimal minerals and vitamins, such as pumpkin seeds, chia seeds, black seeds, and flaxseeds [2.[

Flaxseed (Linum usitatissimum L.), or linseed originating from India, belongs to the family Linaceae and genus Linum, an annual herbaceous cultivated plant with proper amounts of fiber, ash, and oil from its seeds. Phytochemicals such as triterpenoids, steroids, glycosides, saponins, alkaloids, flavonoids, tannins, proteins, free amino acids, carbohydrates and vitamin C are available in the flaxseed [3.[

In traditional medicine, flaxseed was used to treat various human ailments, including constipation, osteoporosis, headache, depression, allergies, psoriasis, hypertension, diabetes, eczema and menopausal symptoms [4.[

Flaxseed oil contains protein and antioxidants with high amount of fatty acid, especially linolenic acid, with various critical physiological and functional features, including cranial nerve development, memory enhancement, immunity improvement, metabolism-boosting, and cerebral thrombosis/myocardial infarction prevention [5.[

Generally, flaxseeds are used in fortified foods, snack foods, bread, macaroni, cartoon bread, cookies, muffins, and cake. Also, they are added to yoghurt, cheese, butter, and milk as flavouring agents and functional food [6,7]; however, supplementation of wheat flour with flaxseed on the rheological properties of flour powder and the baking characteristics of bread is limited.

Food workstations have continuously tried to include alternative healthy ingredients to yield various health-promoting functional foods, such as flaxseed, that can be used in baked properties and other cereal-based products.

Therefore, we aimed to study the benefits of flaxseed for enhancing the nutritional quality

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of loaf breads, that are commonly used in the world, including our region.

Materials and methods

Dough making

Fine wheat flour, flaxseed, sugar, shortening, yeast, salt, and milk for making dough were obtained from the well-known local markets of Sulaimaniyah City, Iraq. Consequently, a wheat flour was replaced by flaxseed flour at three different levels (5%, 10%, and 15%) to prepare loaf bread, while the dough without adding flaxseeds was considered a control (0%). Then the ingredients were correctly mixed; limited tap water was added to make the dough and left at room temperature to ferment for 90 minutes and proof for 33 minutes before baking at 210° C, using an optimized straight-bread-making method 10-10.03 (AACCI, 1983) [8].

Loaf bread quality characteristic

Loaf breads were subjected to physical analysis, including measuring loaf volume using a traditional rapeseed displacement apparatus an hour after baking and removing it from the oven. Loaf weight was determined, while specific volume was calculated as loaf volume (mL)/loaf weight (g) [9].

Rheological characteristic of loaf bread

Before and after adding various concentrations of flaxseed flour to the loaf bread flour, the Farinograph (Model No. 8124; Brabender OHG, Duisburg, Germany) was used to study water absorption, stability (flour strength), peak time (development time), and degree of softening at 10 minutes (mixing tolerance index; MTI). Additionally, the amylase activity as temperature at peak viscosity with gelatinization temperature of the loaf bread was determined using an Amylograph (Model No. 803201, Duisburg, Germany) using AACC method-54-21 [8].

Loaf bread's chemical composition

Moisture content was assessed at 105° C by the indirect method (ICC methods 110/1), proteins by the Kjeldahl method (f=5.71), lipids by the Soxhlet method, and ashes by the direct method using a muffle at 550° C according to AACC [8].

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Sensory evaluation of loaf bread

The bread sensory characteristics were evaluated using semi-trained panellists (n=5). Then, the acceptability, taste, appearance, aroma, crust color, and texture of the samples were assessed on a ten-points hedonic scale, scoring from one (immensely dislike) to ten (extremely like) [10].

Measurements of total phenolic content in loaf bread

One mL of 10-fold diluted Folin-Ciocalteu reagent was added to 3gm of the sample, mixed well, and left for 5 minutes at 25° C. Then, 1.5 mL sodium carbonate (20%) was added, and the volume was completed to 25 mL with distilled water, which was allowed to stand for one hour. The regression equation of gallic acid was y = 0.0037x + 0.0071 (R2 = 0.9981) as shown in Figure (1). Finally, absorbance was documented at 765 nm using a spectrophotometer, and the results were shown as mg of gallic acid equivalent (5-100 µg/mL) per gram dry extract [11].

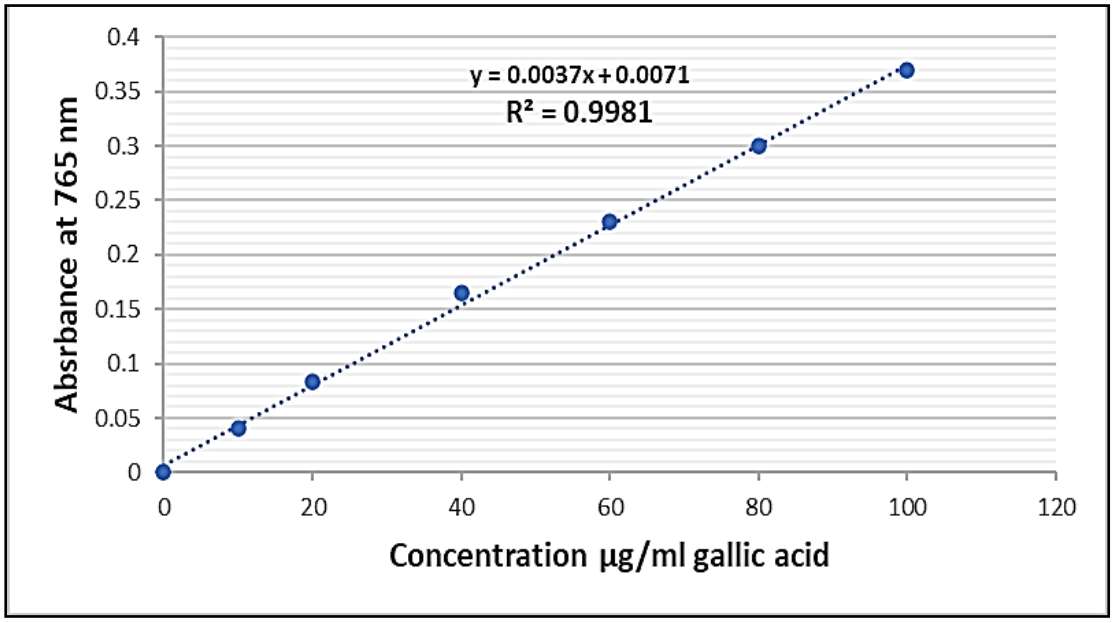

Figure 1. The calibration curve of gallic acid was used to determine the total phenolic content.

Measurements of total flavonoid content in loaf bread

The total flavonoid content of the loaf bread was determined by adding one mL of aluminum chloride (2% in ethanol) and 10 mL of acetic acid to 5g of a sample. The volume was completed to 25 mL with distilled water and left for 45 minutes at room temperature. The regression equation of quercetin was y = 0.0073x + 0.0137 (R2 = 0.9964), as shown in Figure (2). Lastly, the absorbance was measured spectrophotometrically at 430 nm, and the result stated as mg of quercetin

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equivalent (RE; 5 – 25 µg/mL) per gram dry extract [11].

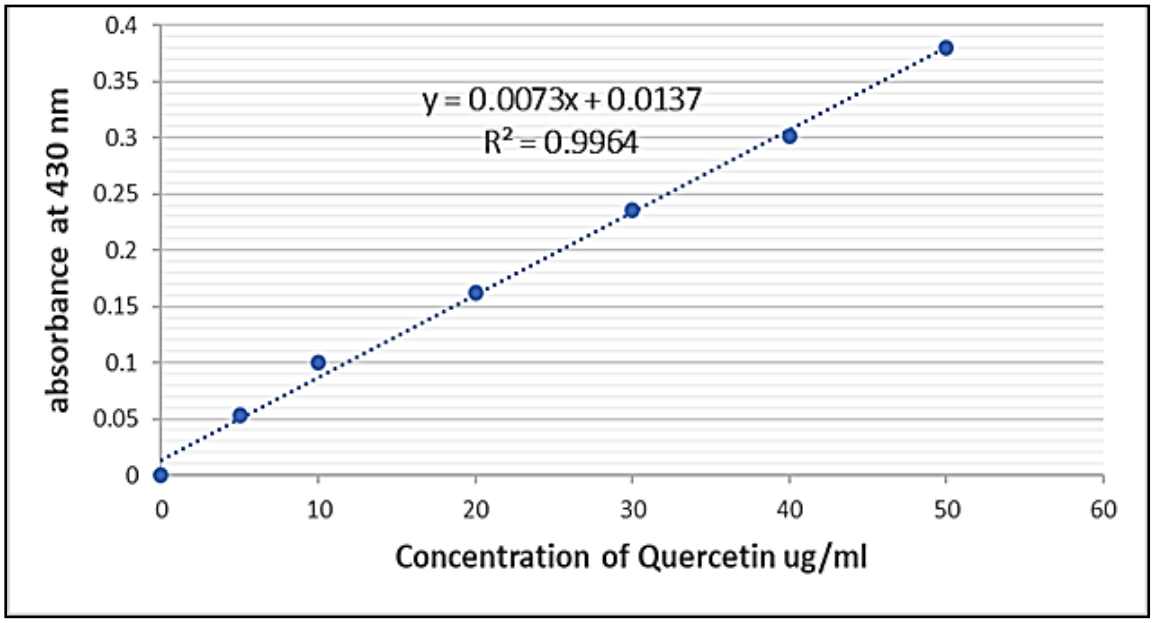

Figure 2. Calibration curve of quercetin at various concentrations.

Textural characteristics of loaf bread

Texture profile analysis (TPA) was made to find the hardness, cohesiveness, and springiness of formulated loaf bread based on a force-time curve [12].

Statistical analysis

The collected data were analyzed using Statistical Package for the Social Sciences (SPSS, IBM, Chicago, USA version 25). Descriptive statistics and inferential statistics were calculated for different variables. Statistical significance between groups was considered at the level of $p \leq 0.05$ using chi-square test.

Results and discussion

Effect of flaxseed flour addition on loaf bread quality

Loaf bread volume and weight have a strong influence on consumer preference. These two values of loaf bread made with various concentrations of flaxseed flour were not significantly different ($p \geq 0.05$) from that of the control sample. The flaxseed flour additions also did not affect the specific volume of the loaf bread, even though the water absorptions were higher for doughs with flaxseed flour (Table 1). In this respect, Khouryieh et al., 2013 [13] reported that 10% flaxseed bread had higher loaf weight, volume and specific volumes than control. In contrast, Marpalle et al. 2014 [14] stated lower loaf volume, weight and specific volumes for 10% flaxseed fortified bread than control. At the same time, Xu et al., 2014 mentioned although more water was used during the dough formation

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step with increasing flaxseed flour concentrations, loaf weight for all of the treatments was not decreased significantly (p> 0.05). They also stated that loaf volume of bread containing flaxseed flour up to 10% did not differ significantly (p>0.05) from the control, whereas further increasing flaxseed flour in the formula reduced loaf volume significantly [9]. This might be due to water evaporation during baking. These outcomes might be correlated to the dilution of gluten and the interference of lignans and dietary fibers available in the flaxseed flour [14].

Table 1. The quality of loaf bread incorporated with flaxseed flour.

Variable	**Flaxseed Flour Replacement Level**				**p-value**
	0%	**5%**	**10%**	**15%**	
Loaf volume (mL)	228	225	219	216	0.057
Loaf weight (g)	75	74	77	78	0.055
Specific volume (mL/g)	3.04	3.00	2.84	2.7	0.058

Effect of flaxseed flour on rheological properties of the loaf bread

Table (2) shows the Farinograph characteristics of the loaf bread before and after adding flaxseed flour into the wheat flour, in which higher values with significant differences (p≤0.05) for all attributes of the incorporated flaxseed flour samples were seen than control. In this regard, the water absorption was gradually increased in the dough along with increasing the concentrations of flaxseed flour from 61.9% in the control to 71.4% after adding 15% of flaxseed flour. Generally, more water absorption means firmer dough because it absorbs high percentages of liquids and retains more carbon dioxide. These results agree with Pourabedin et al., 2017 [15], Xu et al., 2014 [9], and Koneva et al., 2018 [16], while disagreeing with Codină et al., 2019 [17]. These outcomes might be due to dietary fibers' high water binding capacity and gums/mucilage available in flaxseed flour that might compete with the flour protein for water.

Table 2. Farinograph characteristics of loaf bread flour powder incorporated with flaxseed flour.

Flaxseed Flour Replacement Level	Water Absorption (%)	Peak Time (Minute)	Stability (Minute)	Mixing Tolerance Index (Minute)
Control (0%)	61.9	1.5	1.7	118
5%	65.9	2.4	7.4	27
10%	68.4	2.0	11.5	13
15%	71.4	2.4	7.1	17
p-value	0.045*	0.047*	0.025*	0.012*

*: Significant difference compared to control, using Chi-square test

Meanwhile, flaxseed particle size also affects water absorption, as the finer particle size is higher than the water absorption value [18]. Furthermore, the same gradually increasing results were seen for peak time value from 1.5 minutes in the control to 2.4 minutes in the highest concentrations of the flaxseed flour. These outcomes indicate slower development time at higher flaxseed flour amounts, which might be related to less gluten content of flaxseed flour and its water absorption as it requires more mixing time and absorbs more water. On the other hand, the stability significantly increased from 1.7 to 7.1 minutes, while MTI significantly decreased from 118 to 17 minutes. High MTI designates weak flour that inclines the formulated dough to break down rapidly after making a loaf of bread; thus, we indicated that flaxseed flour addition exerted a less softening capacity and high strength effect in the formulated dough. These findings are related to the physical interruption of the gluten matrix that makes the dough weaken and break down more quickly, as the gluten is responsible for the viscoelastic network and dough strength. All these Farinograph characteristics found in this study are similar to those found by Xu et al. 2014, except MTI results that increased significantly from 33 to 82.5 minutes [9].

Table (3) shows that the dough containing flaxseed flour did not include any amylases, which might be due to the starch gelatinization process from the formulated dough. Also, Tmax increased gradually and significantly upon gradually increasing flaxseed flour amounts, which might be related to the starch gelatinization and proteins present in the flaxseed flour. Liu et al., 2020 [20] stated that the increase of Tmax is perhaps due to the aggregation of amylose particles and the

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mucilage content of the flaxseed flour. Consequently, starch granules are insufficiently gelatinized and slowly expanded upon continuous increases in the flaxseed flour concentrations. On contrary, Koneva et al., 2018 stated that viscosity (amylolytic activity) of the wheat flour was decreased after adding flaxseed flour in the ratio of 92.5%:7.5%; 90.0%:10.0% and 87.5%:12.5% that might be contributed to a more rapid maturation of the dough and reduces the total duration of its fermentation 1.5 times [16].

Additionally, flaxseed flour addition to the wheat flour decreases gelatinization temperature and increases Tmax values, which might be due to flaxseed flour competing with water for gluten or other wheat flour ingredients.

Table 3. Amylograph characteristics of the loaf bread incorporated with flaxseed flour.

Flaxseed Flour Replacement Level	**Initial Temperature of Gelatinization (°C)**	**Final Temperature of Gelatinization (°C)**	**Temperature at Peak Viscosity (Tmax)**
Control (0%)	66	90	460
5%	65	88.5	540
10%	65.2	87	700
15%	63	85	620
p-value	0.049*	0.045*	0.048*

*: Significant difference compared to control, using Chi-square test

Bread chemical composition

Table (4) indicates that adding flaxseed flour to the wheat flour results in non-significant ($p \geq 0.05$) decreasing the amount of moisture from 38.2 to 30%. Also, non-significantly ($p \geq 0.05$) increasing each protein (from 10 to 11.98%). However, both ash (1.52 to 2.70%), and lipid contents (from 1.7 to 5%) were significantly ($p \leq 0.05$) increased with increasing concentrations of flaxseed flour. In this respect, Codină et al. (2019), found adding flaxseed flour increases protein, fat, and ash levels with a decrease in moisture content. These outcomes are related to the high flaxseed content in proteins, fats, and ash and its lower moisture content than wheat flour [21]. It was proved that flaxseed improved the

bread quality in terms of moisture and softness during storage due to its gum content [9]. A similar trend of these values with different levels of flaxseed flour addition was also described by Codină et al. 2017 [22], Wandersleben et al. 2018 [23], and Taglieri et al., 2020 [24].

Table 4. Chemical composition of wheat bread and bread with mixtures of flaxseed flour.

Component (%)	Flaxseed Flour Replacement Level				p-value
	0%	%5	%10	%15	
Moisture	38.2	29.4	31.1	30.0	0.567
Protein	10	10.7	9.5	11.8	0.611
Ash	1.52	1.62	1.70	2.70	0.045*
Fat	1.7	1.9	3.5	5.0	0.047*

*: Significant difference compared to control, using Chi-square test

Sensory evaluation of loaf bread

Sensory evaluation of loaf bread containing different amounts of flaxseed flour is shown in Table (5). Loaf bread containing wheat flour alone (0%) had the highest attributes (crust color) than the flaxseed flour treatments. Color is an essential criterion for the consumer's initial acceptability of the baked product. Hence, the highest acceptability was found in loaf bread containing wheat flour alone (0%), while the lowest was found in those containing 15% flaxseed flour. Similar results were accurate for the loaf bread containing wheat flour alone (0%) regarding appearance, texture, and overall acceptability. However, all loaf bread with flaxseed flour addition gave the testers the more preferable tastes and aroma; thus, using up to 15% flaxseed flour in loaf bread would be readily accepted by consumers. In this regard, Sanmartin et al., 2020 [19], Codină et al. 2017 [20], Marpalle et al., 2014 [14] observed that all sensory parameters of the control samples are significantly different ($p \leq 0.05$) from those incorporated with flaxseed flour.

Table 5. Sensory evaluation of loaf bread at different levels of wheat flour substitution with flaxseed.

Variable	Flaxseed Flour Replacement Level				p-value
	0%	5%	10%	15%	
Crust color	8.6	7.8	7.8	8.0	0.047*
Aroma	7.0	7.8	7.8	8.4	0.039*
Taste	7.0	7.6	7.6	7.6	0.046*
Appearance	8.0	7.8	7.4	7.6	0.55
Texture	7.8	7.8	7.0	7.2	0.046*
Overall acceptability	8.2	8.0	7.8	7.4	0.048*

*: Significant difference compared to control, using Chi-square test

Total phenolic content and total flavonoid content in loaf bread

According to the results, increased phenolics (Table 6) and flavonoids (Table 7) in loaf bread were observed with increased flaxseed flour substituting for wheat flour. These might be related to flaxseeds containing various phytochemical compounds with antioxidant characteristics, including phenolic acids, flavonoids, and lignans. Similar results for total phenolic content of flaxseed flour were seen by Pourabedin et al. 2017 [15]. Whereas Gao et al., 2022 found that the defatted flaxseed flour had the highest total flavonoid content content among different types of flaxseed used to make Chinese steamed bread because flaxseed is mainly a nonfat soluble substance [7].

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Table 6. Measurements of total phenols in loaf bread by the Folin-Ciocalteu method.

Sample No.	Flaxseed Flour Replacement Level	Visibility Absorbent at 765 nm	Concentration of Sample (µg/mL)	GAE/g Dry Sample
1	0%	0.109	27.54	0.918
2	5%	0.208	54.23	1.807
3	10%	0.253	66.45	2.215
4	15%	0.334	88.35	2.945

Table 7. Calculation of total flavonoid content.

Sample No.	Flaxseed Flour Replacement Level	Visibility Absorbent at 430 nm	Concentration of Sample (µg/mL)	QE/g Dry Weight
1	0%	0.112	13.46	0.269
2	5%	0.157	19.63	0.392
3	10%	0.193	24.56	0.491
4	15%	0.232	29.90	0.598

Effect of adding flaxseed flour on textural characteristics of loaf bread

As observed in Table (8), adding flaxseed flour into wheat flour significantly ($p \leq 0.05$) increased each loaf of bread's hardness, cohesiveness, and springiness. These results mean that loaf bread crumb structures were not drastically impaired upon substitution of wheat flour by up to 15% flaxseed flour. In this respect, Liu et al. 2020 [20] indicated that flaxseed flour addition at various levels significantly ($p \leq 0.05$) increased the hardness of Chinese steamed bread but decreased the cohesiveness and springiness. A similar result was also observed by Zhu and Li, 2019 [5], where flaxseed flour addition affected the textural assets of bread. The loss of flour powder structure after diluting the gluten and starch matrix may reduce its gas-holding capacity and decrease specific volume that might increase the hardness and the bread's cohesiveness and springiness [20].

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Table 8. Changes in the texture parameters of bread loaf were incorporated with flaxseed floor (FF).

Variable	Flaxseed Flour Replacement Level				p-value
	0%	5%	10%	15%	
Hardness (g)	547	479.5	509.5	649	0.037*
Cohesiveness	0.77	0.85	0.80	0.84	0.045*
Oven springiness (mm)	4.6	4.8	4.8	4.9	0.045*

*: Significant difference compared to control, using Chi-square test

Conclusions

Replacement of wheat flour with various concentrations of flaxseed flour significantly affected rheological parameters, including increment of the water absorption, stability, development time, and Tmax with decrement in the degree of softening at 10 minutes and gelatinization temperature. The increased concentration of flaxseed flour considerably affected the chemical content, sensory, and texture of loaf bread. Further studies are recommended to be done using more concentrations of flaxseed flour with various techniques and different types of flour and confectionery.

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Ethical considerations

Not applicable.

Conflict of interest

Not declared.

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Data availability

The raw data of this study is available with the main author (https://sites.google.com/a/univsul.edu.iq/shler-fayak/) and can be provided upon request.

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