Egypt. J. Chem. **Vol. 66**, No. 5 pp. 261 - 271 (2023)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

The Impact of Inulin and Chia Mucilage on Biscuit Formula as a Fat Replacer

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Abstract

The aim of this work was to evaluate the effect of replacing wheat flour with wheat germ (10 and 20%) or fat by different fat replacers, including inulin (20 and 40%) and chia mucilage (10, 15, and 20%) on the quality attributes and physicochemical properties of biscuits. The results showed that the wheat germ substitution significantly ($P \leq 0.05$) increased the protein, ash, and crude fiber content of biscuits compared to the control sample. The fat content progressively increased with the increment substitution levels of wheat germ. Moreover, the fat content gradually decreased with the increase in the fat replacer's content. There were no significant differences ($P \leq 0.05$) in the protein content between the control sample and other samples prepared with different ratios of fat replacers. The results also indicated that the fat replacement by inulin or chia mucilage reduced the specific volume of the biscuit compared to the control sample. Our findings indicated that utilizing inulin by 30 and 40% significantly reduced fat content by 45.32 and 58.33%, however 20% chia mucilage decreased fat content by 22.36% in biscuit samples. Reducing the fat content by inulin and chia mucilage as fat replacers increased the hardness and decreased the fracturability values of the produced biscuits compared to the control sample. According to the organoleptic findings, there were no significant differences ($P \leq 0.05$) between the control and other treated samples in terms of color and texture criteria. Using chia mucilage as a fat replacer at a level of 20% improved the overall acceptability of the biscuit compared to the control sample.

***Keywords*:** wheat flour, wheat germ, obesity diet, healthy diet, low-fat foods.

1. Introduction

Bakery products are widely consumed food products worldwide [1]. Particularly, biscuits are extensively consumed all over the world, they have higher contents of calories, fat, and carbohydrates. Biscuit is an ideal product for protein fortification and other nutritional benefits due to its acceptable taste and longer shelf life [2,3]. Moreover, biscuits have become attractive for all ages due to their affordable cost, availability in different varieties, high nutritional value, and their ready-to-eat nature [4]. It is well known that the fat in biscuit dough serves various crucial purposes. Fat interacts with other components in the dough to generate the proper texture, an essential food quality aspect since it affects sensory perception and gives the final product its shape and stability [5].

In general, fat has a wide range of uses in baked foods; its primary purposes include providing tenderness, richness, and shortening to enhance the mouthfeel and flavor. Shortening offers some beneficial effects on bakery foods, such as prolonged shelf life, heat transfer, air incorporation, lubrication, structural integrity, mouthfeel, tenderness, and texture [6].

Consumers are increasingly aware of the relationship between nutrition and health today [7]. Saturated fat consumption can increase blood cholesterol levels and the risk of cardiovascular diseases [8]. Thus, food producers have responded to the consumers' needs by introducing low-fat products to the market [9]. Although it is possible to partially substitute fat with other nutrients like dietary fiber, eliminating fats and oils would significantly reduce the product's original integrity [10]. Therefore, the increased interest in high-dietary fiber and low-calorie foods has been linked to obesity, especially among teenagers and children in developed nations. As a result, researchers are looking for specific compounds that can successfully substitute sugar or fat without affecting the sensory qualities of food products. Consumers have no health risks when using these substitutes in food products in particular amounts and in compliance with good manufacturing practice guidelines [11].

Although customers often associate reduced-fat food products with having lower sensory qualities, they can assist in managing diet-related health issues. Therefore, to create appealing reduced-fat goods, high-quality fat replacers are required [12]. Thus, the

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Receive Date: 15 February 2023, Revise Date: 14 March 2023, Accept Date: 20 April 2023.
DOI: 10.21608/ejchem.2023.194048.7611

inclusion of fat substitutes in different food products was thoroughly researched. However, the complete removal of fat and its replacement with another element is challenging and does not always induce the desired outcomes [13].

Inulin is one of the compounds that has been recently utilized as a fat replacer. The primary inulin sources are the *Compositae* Family plants [14]. Chicory is the primary source of inulin on a large scale. It is employed as a food ingredient in health-promoting foods due to its properties and ability to substitute fat without requiring significant technological modifications. It may be blended with water or added to other components. By lowering the dietary fat intake, the use of inulin in the production of functional foods could lower cholesterol levels in the blood [15].

Recently, there has been increased interest in using the chia seeds mucilage in the food sector. There are no viable extraction techniques to extract mucilage due to the limited research, low yield, and poor extractability. The effect of a partial fat substitution on the physical properties of the biscuits is examined after replacing fat with the extracted mucilage powder in the form of a gel. Including chia mucilage gel improved the firmness of the biscuits [16].

The aim of this investigation was to incorporate wheat germ, and different fat replacers including inulin and chia mucilage in biscuit formulas and study incorporation effects on the physiochemical, texture, and sensory characteristics of produced biscuits compared to the control biscuit.

2. Materials and Methods

Materials

Wheat flour (soft, 72% extraction), was obtained from the Wadi EL Molok flour Mills Company (6 October, Giza, Egypt). Inulins (Frutafit CLR), chia seeds, wheat germ were obtained from AWA Food Solution Company (Borg Alarab, Alexandria, Egypt), potassium sorbate was purchased from El-Gomhoria Trading Chemicals and Drugs, Cairo, Egypt. Butter, salt, sugar and skim powder milk, fresh egg, vanilla, baking powder were obtained from local market, Giza, Egypt.

Methods

Preparation of chia seeds mucilage:

Chia mucilage extraction was performed according to the method proposed by Avila-de la Rosa *et al.* [17] with some modifications. A sample of 40 g of whole chia seeds was placed in a 1 L beaker and warm Milli-Q water was added at ratio (1:20 w/v), stirred with a magnetic stirrer for 3 h at a constant temperature of 60 °C. The mucilage was separated from the seeds by high speed centrifuge (Pro-Centrifuge, Centurion Science Limited, UK) for 20 min at 3382 xg, and then dried at 70 °C for 48 hours.

Preparation of biscuit

Biscuit samples were prepared according to Schober *et al.* [18] with some modifications, the ingredient composition for biscuit formulation is listed below (Table 1). In a lab mixer, the dough preparation was completed. A low-speed creaming process thoroughly combined the sugar, fat, and mucilage gel. The flour was mixed with vanilla essence, sodium chloride, and sodium bicarbonate. The dough was properly mixed after pouring the required amount of water. The cream was then added. The biscuits were made with a 50 mm-diameter round cutter and baked for 10–12 minutes at 180°C on an aluminum baking sheet. The biscuits were cooled and kept for analysis in aluminum pouches, at room temperature (25±2 °C).

Analytical methods

Falling number

The Falling Number was determined according to AACC [19] International method 56-81.03:

Determination of Falling Number. Samples were determined by FN 1500 **(**Perten instruments AB, Hagersten, Sweden).

Gluten and gluten index

Wet and dry gluten, as well as the gluten index of flour were determined by using Glutomatic system 2200 (Perten instruments AB, Hagersten, Sweden) according to AACC [19] (38-12.02). according to the following equations:

$$\text{Wet gluten content, \% (14\% moisture basis)} = \frac{\text{Total wet gluten x 860}}{100 - \text{\% Sample moisture}}$$

$$\text{Dry gluten content, \% (14\% moisture basis)} = \frac{\text{Total dry gluten x 860}}{100 - \text{\% Sample moisture}}$$

$$\text{Gluten index (GI)} = \frac{\text{Wet gluten remained on sieve (g)}}{\text{Total wet gluten (g)}} \times 100$$

Table 1. Biscuit formulas.

Ingredients	Control	Wheat germ		Inulin		Chia mucilage			Mixture	
		20%WG	40%WG	30%In	40%In	10%Mu	15%Mu	20%Mu	Mix1	Mix2
Soft wheat flour (g)	500.0	400.0	300.0	500.0	500.0	500.0	500.0	500.0	300.0	400.0
Baking powder (g)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Sugar (g)	150.0	150.0	150.0	150.0	130.0	150.0	150.0	150.0	150.0	130.0
Butter (g)	100.0	100.0	100.0	70.0	60.0	90.0	85.0	80.0	60.0	45.0
Fresh egg (g)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Potassium sorbate (g)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vanilla (g)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Inulin (g)	-	-	-	30	40	-	-	-	30	40
Mucilage Chia (g)	-	-	-	-	-	10	15	20	10	15
Wheat germ (g)	-	100	200	-	-	-	-	-	200	100

WG= wheat germ, In= inulin, Mu= mucilage, Mix= mixture

Rheological properties of wheat flour

Farinograph test:

The farinograph (877563 Brabender Farinograph Germany HZ 50) was employed to investigate the mixing and hydration characteristics of the dough according to the AACC official method [19].

Extensograph test:

The extensograph test was performed according to the method described in the AACC [19] using an Extensograph (type: 4821384, Brabender Extensograph Germany HZ 50).

Alveograph test:

Alveograph test was performed using an Alveograph MA 82 (Chopin, Tripetteet Renaud, France) following the approved Method 54-30A [19].

Chemical composition

Chemical analysis was conducted on raw materials and final products. The contents of total ash, crude fiber, crude fat, protein, and moisture of used flour and the produced biscuits according to the AOAC official method [20]. Total carbohydrates were calculated by difference.

Quality attributes of biscuit

To assess the prepared biscuits for the weight (g), diameter (mm), and thickness (mm), Manohar and Rao [21] method was used. Using a computerized weighing balance, the weight of the biscuit was calculated as the average weight of six different biscuits. The biscuits were then piled on top of one another and placed edge-to-edge to measure their diameter and thickness, respectively. The measurements were then averaged. The following equations were used to obtain the spread factor and spread ratio.

Spread ratio = diameter / thickness

Spread factor % = spread ratio of sample /spread ratio of control ×100

Texture profile analysis of biscuits

Textural analysis was performed by Texture analyzer (TA-XTi2 Stable Microsystems, Surrey, UK). The three-point break evaluation method was used to analyze four cookies from each sample. Compression strength test procedures were utilized in the following conditions: trigger force of 50 g, test speed of 1 mm/s, pretest speed of 2 mm/s, and distance of 2.5 mm. Both the fracturability (mm) and hardness (g) were measured.

Color measurement

Using a handheld Chroma Meter (model CR200, Minolta, Tokyo, Japan). Color was measured based on L^*, a^*, and b^* values, where b^* represents the degree of yellow-blue color (a^* higher positive b^* value indicates more yellow). The a^* represents the degree of red-green color (redder is indicated by a higher positive a^* value). L^* represents lightness and ranges from 0 to 100. To calibrate the colorimeter, a conventional white and black plate was used [22].

Organoleptic characteristics of biscuits

The sensory characteristics of biscuits were evaluated according to the method of Manohar and Rao [21], with some modifications by a panel of ten experienced judges from Egyptian Baking Technology Center, Elahram St., Giza. Assigning scores for various quality attributes such as appearance (20), color (20), taste (20), texture (20), odor (10), mouthfeel (10) and overall acceptability (100) of biscuits was evaluated according to the total scores as 90-100 very good (V), 80-89 good (G), 70-79 satisfactory (S) and less than 70 questionable (Q).

Statistical analysis:

Analysis of variance (ANOVA) test was applied for results of organoleptic evaluation of different samples of biscuits, which were treated as data for complete randomization design by using Excel 2010 and least significant difference (L.S.D.) was calculated at 0.05 level of significance.

3. Results and Discussion

Physico-chemical characteristics of wheat flour

The approximate chemical composition of used wheat flour (72% extraction rate) and other quality parameters, including gluten content (wet and dry gluten), gluten index and falling number were determined, and the results are presented in Table 2. According to the obtained results, it could be noticed that the wheat flour sample recorded 12.50% of moisture content. The contents of other components, including ash, protein, fat, fiber, and total carbohydrates, are as follows; 0.54, 10.20, 1.30, 0.63, and 87.33%, respectively. The results also indicated that wheat flour recorded 22.10% of wet gluten with a higher value of gluten index (96.70%), as well as 396 sec. for falling number. These results are in harmony with the findings of Shebl *et al.* [23], who studied the approximate chemical composition of strong and all-purpose wheat flour samples and found that the percentages of moisture, ash, protein, total lipid, and total carbohydrates were 13.5, 0.53, 10.6, 1.11, and 87.7 % respectively, for all-purpose flour.

Hussein *et al.* [24] also studied the gross composition of wheat flour (72%), and stated that it contained 10.90% protein, 1.22% fat, 0.45% crude fiber, and 86.40% total carbohydrates. Five popular brands of self-rising flour in markets contain different percentages of protein (6.70-10%). This wide range of protein content of commercial self-rising flours suggests that the protein level of flour might not be a crucial aspect of wheat for biscuits production. But until now, few studies investigated the wheat qualities needed to produce biscuits with high quality [25]. Therefore, it is primarily used for food products such as cakes, muffins, pancakes, biscuits, and other related products. It has a low protein content and a soft kernel texture [26].

Table 2. Gross chemical composition of wheat flour (72% extraction rate)

Criteria	Wheat flour
Moisture (%)	12.5
Total ash (%)	0.54
Crude protein (%)	10.2
Crude fat (%)	1.3
Crude fiber (%)	0.63
Total carbohydrates (%)	87.33
Wet gluten (%)	22.1
Dry gluten (%)	7.4
Gluten index (%)	96.7
Falling. No (sec.)	396

Rheological properties of used wheat flour

The rheological properties of dough are frequently evaluated by farinograph, extensograph and alveograph tests to evaluate the rheological properties of dough and to evaluate other characteristics during mixing and establish the flour behavior during biscuit-making processes. Table 3 shows the farinograph parameters of used wheat flour. It could be seen that the water absorption was recorded to be 55.10% with 1.50 min of mixing time. Furthermore, a lower value of dough stability was observed (1.50 min). Also, the same sample recorded 96.0 and 72.0 B.U. for mixing tolerance index and dough weakening, respectively.

Extensograph test provides the viscoelastic behavior data of dough [27], represented by dough extensibility and resistance to extension. Good extensibility and acceptable resistance results are needed in dough properties [28]. Where the dough's extensibility is the dough's ability to extend or stretch, it depends on the gliadin protein in the dough. The obtained data (Table 3) showed that the used wheat flour recorded 660 B.U. as resistance to extension (R), 180 mm for extensibility (E). Consequently, R/E was calculated to be 3.70 as a proportional number.

Table 3. Rheological properties of used wheat flour

Rheological parameters	Wheat flour
Farinograph parameters	
Water absorption (%)	55.1
Mixing time (min)	1.5
Stability time (min)	1.5
Mixing tolerance index (B.U)	96
Weakening of Dough (B.U)	72
Extensograph parameters	
Resistant to extension (R) (B.u)	660
Extensibility (E) (mm)	180
Proportional number (R\E)	3.7
Energy (Cm^2)	122
Alveograph parameters	
W (Jol)	208
P (mm)	125
L (mm)	40
(P/L Ratio)	3.13

On the other hand, the area under the peak was found to be 122.0 cm^2 as energy. Variance in rheological properties might commonly be attributed to the difference in chemical composition and structure of the constituents, including starch and protein, and their relations [29].

The alveograph data of wheat flour also are presented in Table 3. The obtained results indicated that wheat flour recorded 208 Jol for the flour strength (W), and 125 mm of tenacity (P). While the extensibility parameter (L) was found to be 40 mm. accordingly, the P/L ratio was recorded at 3.13.

Chemical composition of biscuit samples

The chemical composition of biscuit samples prepared from 100% soft wheat flour as a control sample and the effect of partial wheat flour substitution with different ratios of wheat germ (20 and 40%) were determined. Also, partial fat substitution with inulin (30 and 40%) or chia mucilage (10, 15, and 20%) as fat replacers. Moreover, the effect of incorporating the previous additives (wheat germ-inulin-chia mucilage) was also determined. Moisture content in biscuits is one of the essential sensory characteristics and is responsible for their [30]. According to the obtained results (Table 4), the moisture content of biscuit samples ranged from 3.00 to 3.77% with no significant differences ($P \leq 0.05$) between the moisture content of the control sample (3.00%) and others except samples contained 15, 20% chia mucilage and two mix samples. This was due to the water-holding property of the chia mucilage, as reported by Nayani and Rao [16]. Comparable results were reported by Fernandes and Salas-Mellado [31] who replaced fat by chia mucilage gel in other bakery products.

Table 4. Chemical composition of biscuit samples.

Samples	Chemical composition (% on dry weight basis)					
	Moisture	**Protein**	**Fat**	**Fiber**	**Ash**	**T. Carb.**
1	3.00^{c}±0.09	11.26^{c}±0.14	11.76^{c}±0.26	0.56^{g}±0.05	0.93^{f}±0.07	75.49^{cd}±1.45
2	3.04^{c}±0.10	13.30^{b}±0.18	13.08^{b}±0.04	2.29^{d}±0.11	1.38c^{de}±0.08	69.96^{e}±1.59
3	3.03c±0.03	16.50^{a}±0.15	14.49^{a}±0.23	3.93^{b}±0.13	2.05^{a}±0.10	63.04^{g}±0.95
4	3.13^{c}±0.05	11.28^{c}±0.16	8.19^{g}±0.04	1.01^{ef}±0.05	1.07^{def}±0.07	78.46^{b}±2.43
5	3.26^{bc}±0.07	11.29^{c}±0.15	6.86^{h}±0.12	1.25^{ef}±0.14	1.18c^{def}±0.03	79.44^{a}±2.66
6	3.17^{bc}±0.08	11.35^{c}±0.07	10.42^{d}±0.11	0.97^{f}±0.04	1.06^{ef}±0.05	76.21^{c}±1.87
7	3.51^{ab}±0.14	11.50^{c}±0.14	9.81^{de}±0.09	1.14^{ef}±0.04	1.26^{cdef}±0.06	76.31^{cd}±1.33
8	3.77^{a}±0.07	11.50^{c}±0.14	9.13^{ef}±0.10	1.37^{e}±0.05	1.52^{bc}±0.09	76.49^{cd}±2.41
9	3.32^{b}±0.13	16.70^{a}±0.25	8.42^{fg}±0.32	4.48^{a}±0.09	1.86^{ab}±0.08	68.55^{f}±2.11
10	3.54^{ab}±0.03	13.60^{b}±0.14	6.13^{i}±0.24	3.30^{c}±0.19	1.44^{cd}±0.07	75.54^{d}±1.73

**Means in each column sharing the same superscript letter are not significantly different (P≤0.05).*
Where: 1=100% wheat flour, 2= 20% wheat germ, 3= 40% wheat germ, 4= 30% inulin, 5= 40% inulin, 6= 10% chia mucilage, 7= 15% chia mucilage, 8= 20% chia mucilage, 9= mix 1 (30% inulin + 10% chia mucilage + 20% wheat germ) and 10= Mix 2 (40% inulin + 15% chia mucilage + 10% wheat germ).

Regarding the protein content, no significant differences (*P*≤ 0.05) were observed after adding fat replacers (inulin and chia mucilage) compared to the control sample (100% wheat flour). On the contrary, the replacement of wheat flour with various levels of wheat germ significantly increased the protein content of produced biscuits. The highest values of protein content were observed by samples Mix 1 and other contained 40% wheat germ (16.70, and 16.50% respectively) with non-significant differences between them and with significant differences compared to other samples (*P*≤ 0.05). These findings were correlated with the findings of Al-Marazeeq and Angor [32], who stated that replacing wheat flour with 40% wheat germ increased the total protein content by 29 %.

Concerning the fat content, the replacement of butter by inulin and chia mucilage at different ratios significantly (*P*≤ 0.05) decreased the fat content of the biscuits compared to the control sample. On the contrary, replacing wheat flour with 20 and 40% wheat germ (samples 2 and 3) significantly increased the fat content compared to the control sample. It was found that replacing of fat by inulin (30 & 40%) reduced the fat content by 45.32 and 58.33% respectively. Also, utilizing chia mucilage by 20% reduced fat content by 22.36%, however, the mixture of fat replacers (Mix 1 & Mix 2) reduced fat by 28.40 & 41.88% in biscuit samples, these results are in agreement with El-Refai *et al.* [33] they mentioned that fat replacers can substitute fat in bakery products and produce reduced-fat options which will be able to match the quality of their full-fat complements. On the other hand, supplementing biscuits with wheat germ at various levels increased crude fiber and ash content as the replacement ratio increased. However, the highest values of total carbohydrate content significantly recorded by the samples contained 30 and 40% of inulin, respectively.

Effect of wheat germ supplementation and fat replacers on biscuit color

Color is a critical quality attribute because it can arouse an individual's appetite. Additionally, it is one of the factors used for the control process during baking because the brown color appears as browning and caramelization reactions progress [34]. The color parameters of the biscuit samples (L^*, a^* *and* b^*) were measured, and the results are shown in Table 5. From the obtained results, it can be concluded that L^* values (lightness) and a^* values (redness) decreased with directly proportional to the replacement ratios of wheat germ compared to the control.

Table 5. Color measurement of biscuit samples.

Samples	Color parameters of biscuit		
	L*	***a****	***b****
1	69.77^{bc}±0.32	8.14^{a}±0.19	28.43^{c}±0.62
2	67.50^{d}±0.70	6.78^{bcd}±0.31	31.61^{b}±0.85
3	64.75^{e}±0.35	5.72^{d}±0.40	35.37^{a}±0.55
4	70.20^{bc}±0.28	7.84^{ab}±0.23	28.29^{c}±0.40
5	70.41^{bc}±0.21	7.51^{ab}±0.23	28.32^{c}±0.44
6	71.20^{b}±0.28	7.78^{ab}±0.31	28.83^{c}±0.40
7	73.78^{a}±0.16	7.55^{ab}±0.14	29.84^{bc}±0.23
8	75.36^{a}±1.35	7.16^{abc}±0.21	31.49^{b}±0.40
9	67.49d±0.53	6.16^{cd}±0.38	34.17^{a}±0.19
10	68.53^{cd}±0.04	7.06^{bc}±0.08	31.73^{b}±0.50

**Means in each column sharing the same superscript letter are not significantly different (P≤0.05).*
Where: 1=100% wheat flour, 2= 20% wheat germ, 3= 40% wheat germ, 4= 30% inulin, 5= 40% inulin, 6= 10% chia mucilage, 7= 15% chia mucilage, 8= 20% chia mucilage, 9= mix 1 (30% inulin + 10% chia mucilage + 20% wheat germ) and 10= Mix 2 (40% inulin + 15% chia mucilage + 10% wheat germ).

However, no significant differences (*P*≤ 0.05) were obtained between the control sample and others replaced with different ratios of inulin or chia mucilage concerning *a** and *b** values, except the sample contained 20% mucilage which recorded a higher value (31.49) of yellowness (*b**) compared to 28.43 obtained by the control sample. These results are confirmed by the results of Sudha *et al.* [13], who stated that the color of the biscuit became pale with fat reduction, and the appearance decreased significantly. Also, Nayani and Rao [16] reported that the color of the biscuits changed from light brown to creamy yellow as the level of mucilage gel increased.

Effect of wheat germ supplementation and fat replacers on physical properties of biscuits.

The influence of wheat flour replacement by wheat germ and butter replacement by fat replacers (inulin and chia mucilage) at different ratios on the physical properties of biscuits was studied, and the obtained results are shown in Table 6. The control sample recorded the lowest value of weight (17.55 g) with a significant difference (*P*≤ 0.05) compared to other samples, except the samples contained 30 and 40% of inulin (17.27 and 18.22 g, respectively). However, no significant differences (*P*≤ 0.05) were observed between the control and other samples except the samples contained of 30 and 40% inulin regards the biscuit volume. Consequently, the specific volume was calculated to show that the control sample significantly recorded the highest value (1.66 cm^3/g).

Additionally, the thickness and diameter of the biscuit samples were measured to obtain the spread ratio (diameter/thickness), and the replacement of wheat flour by 20 and 40% wheat germ increased the spread ratio (11.61 and 12.81%, respectively) compared to the control sample (10.30%).

Table 6. Physical properties of biscuit samples.

Samples	Quality parameters of biscuit samples					
	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)	Thickness (cm)	Diameter (cm)	Spread ratio (%)
1	17.55f±0.64	29.00a±1.40	1.66a±0.17	0.52c±0.02	5.35ab±0.17	10.30bc±0.41
2	20.83de±0.24	29.02a±2.58	1.39c±0.11	0.44ef±0.03	5.05bc±0.09	11.61ab±0.20
3	22.16cd±0.22	28.06ab±0.97	1.27e±0.12	0.41f±0.01	5.25ab±0.11	12.81a±0.26
4	17.27f±0.38	26.27bc±0.38	1.52b±0.09	0.49cde±0.03	5.05bc±0.13	10.31bc±0.15
5	18.22f±0.30	25.25c±1.22	1.39c±0.09	0.46def±0.01	4.60c±0.09	10.13bcd±0.78
6	20.61e±0.55	27.75ab±1.35	1.35cd±0.12	0.59b±0.03	5.60ab±0.09	9.50cde±0.46
7	22.03cd±0.23	28.10ab±2.14	1.28de±0.15	0.62ab±0.03	5.30ab±0.12	8.55de±0.03
8	22.99bc±0.41	28.15ab±1.21	1.23ef±0.11	0.66a±0.06	5.15bc±0.16	7.86e±0.07
9	23.72ab±0.40	27.90ab±1.41	1.18fg±0.09	0.53c±0.04	5.78a±0.11	11.01bc±0.48
10	24.84a±0.33	28.00ab±1.32	1.13g±0.11	0.51cd±0.06	5.35ab±0.09	10.50bc±0.70

***Means in each column sharing the same superscript letter are not significantly different ($P \leq 0.05$).**
Where: 1=100% wheat flour, 2= 20% wheat germ, 3= 40% wheat germ, 4= 30% inulin, 5= 40% inulin, 6= 10% chia mucilage, 7= 15% chia mucilage, 8= 20% chia mucilage, 9= mix 1 (30% inulin + 10% chia mucilage + 20% wheat germ) and 10= Mix 2 (40% inulin + 15% chia mucilage + 10% wheat germ).

In contrast, the samples contained various levels of chia mucilage (10,15, and 20%) led to a gradual decrease in the same parameter (9.50, 8.55, and 7.86%, respectively) compared to the control sample. As for the effect of inulin addition, no significant differences ($P \leq 0.05$) were observed between the control sample and others that contained 10 or 20% of inulin as a fat replacer.

Effect of wheat germ supplementation and fat replacers on texture analysis of biscuits.

The texture profile of the control biscuit (100% wheat flour) and other treated samples with different ratios as fat replacers are presented in Table 7. These observations can be related to the hardness of these biscuits, which tended to decrease as the fat content ratios were reduced. The replacement of wheat flour by20 and 40% of wheat germ recorded the lowest hardness values (45.87 and 39.74 N, respectively), followed by the control sample (55.22 N).

Table 7. Texture profile analysis of biscuit sample.

Samples	Texture parameters of biscuit samples	
	Hardness (N)	Fracturability (mm)
1	55.22	77.41
2	45.87	81.95
3	39.74	97.54
4	81.37	59.70
5	86.81	39.58
6	93.99	58.21
7	121.98	36.38
8	124.41	33.40
9	106.9	58.54
10	121.3	45.31

Where: 1=100% wheat flour, 2= 20% wheat germ, 3= 40% wheat germ, 4= 30% inulin, 5= 40% inulin, 6= 10% chia mucilage, 7= 15% chia mucilage, 8= 20% chia mucilage, 9= mix 1 (30% inulin + 10% chia mucilage + 20% wheat germ) and 10= Mix 2 (40% inulin + 15% chia mucilage + 10% wheat germ).

On the other hand, the replacement of added butter with different levels of inulin (10 and 20%) or chia mucilage (10, 15, and 20%) led to an increase in the hardness values compared to the control sample; these findings was explained by Rodríguez-García *et al.* [35] who stated that when high-fat content is present in the dough formulation, fat was distributed surrounding flour particles, thus limiting its hydration and hindering amilo-protein interactions. This result is supported by previous studies [6], who stated that in baked products without shortening, gluten and starch particles adhere to each other and give the sensation of hardness and toughness when chewed. Also, Chysirichote *et al.* [36] mentioned that reducing the fat content in the outer crust of flaky Chinese pastry increased the hardness of the pastry and tended to decrease the specific volume and puffiness.

Concerning the effect of fat replacers on the fracturabilty parameter, it was found that the replacement of butter by inulin or chia mucilage at different substitution levels led to a decrease in the fracturability values compared to the control sample (77.41 mm). While the replacement of wheat flour with wheat germ (20 and 40%) increased the fracturability of biscuit samples. Thus, the ability of a biscuit to regain its original form is measured in terms of fracturability. These results agreed well with Nayani and Rao [16], who studied the effect of chia mucilage in biscuits as a fat replacer and found that fracturability of the biscuit samples significantly reduced as the level of mucilage increased ($P \leq 0.05$).

Effect of wheat germ supplementation and fat replacers on sensory evaluation of biscuits.

The sensory evaluation of fat-replaced biscuits with inulin and chia mucilage, and other biscuit samples fortified by 20 and 40% of wheat germ compared with the control sample was applied and the results presented in Table 8. It can be observed that there was no significant ($P \leq 0.05$) difference between the control sample and other treated samples in terms of the biscuit color and texture. Meanwhile, the control sample recorded higher values of appearance and taste (17.50 and 17.40 respectively) with significance differences only with the samples containing 30% inulin, Mix 1 and Mix 2. It was found that, no significant differences among all samples concerning color and taste parameters. The panelists were asked to show their observation via sensory evaluation in wording, the observations including samples 2 and 7 were they recorded very tough texture, however sample 4 exhibited soft and good texture. Furthermore, such sample exhibit best sample with a good taste and smell as an opinion of the most panelists.

Concerning the overall acceptability, the replacement of fat by 30% inulin and other replaced by 20% of chia mucilage showed significantly ($P \leq 0.05$) higher values (83.40 and 86.70, respectively)

Table 8. Sensory evaluation of biscuit samples.

Samples	Sensory parameters of biscuit samples							
	Appearance (20)	Color (20)	Taste (20)	Texture (20)	Odor (10)	Mouthfeel (10)	Overall acceptability (100)	Observations
1	$17.5^{ab}\pm1.96$	$17.4^{a}\pm2.07$	$17.4^{a}\pm2.11$	$14.3^{a}\pm4.42$	8.7a±1.05	7.4abc±1.71	82.7b±3.70	
2	$15.9^{abcd}\pm1.8$	$15.2^{a}\pm3.39$	$13.1^{cde}\pm5.1$	$13.6^{a}\pm6.48$	6.5cd±2.22	5.9cd±2.77	70.2d±4.08	very tough
3	$13.6^{d}\pm1.98$	$14.3^{a}\pm3.71$	$12.7^{de}\pm4.73$	$12.2^{a}\pm6.05$	6.1d±2.13	4.8d±2.45	63.7f±3.90	-
4	$18.1^{a}\pm2.28$	$17.5^{a}\pm2.84$	$16.1^{abc}\pm3.1$	$16.0^{a}\pm1.94$	8.0abc±1.9	7.7ab±1.89	83.4a±4.98	Soft, no cracks
5	$17.2^{abc}\pm1.7$	$17.0^{a}\pm2.31$	$14.4^{abcde}\pm2.9$	$15.5^{a}\pm4.00$	7.1bcd±1.7	6.1bcd±1.97	77.3c±4.78	-
6	$15.1^{bcd}\pm2.6$	$15.8^{a}\pm2.10$	$15.3^{abcd}\pm1.59$	$16.0^{a}\pm3.05$	7.3abcd±1.4	6.0bcd±1.42	75.5cd±3.98	-
7	$15.5^{abcd}\pm2.7$	$15.5^{a}\pm2.42$	$16.4^{ab}\pm2.17$	$15.9^{a}\pm3.44$	7.4abcd±1.7	7.4abc±1.74	78.1c±4.76	very tough
8	$17.5^{ab}\pm2.27$	$17.2^{a}\pm2.62$	$17.4^{a}\pm2.91$	$17.6^{a}\pm2.31$	8.5ab±1.17	8.5a±1.43	86.7a±5.87	best sample and good taste and smell
9	$14.8^{cd}\pm3.29$	$14.8^{a}\pm3.36$	$13.4^{bcde}\pm3.4$	$12.6^{a}\pm3.02$	6.9cd±1.66	6.6bc±1.65	69.1d±3.98	-
10	$14.1^{d}\pm3.35$	$14.7^{a}\pm3.1$	$11.7^{e}\pm4.96$	$14.30^{a}\pm5.0$	6.5cd±2.01	6.2bcd±1.87	67.5e±4.76	-

**Means in each column sharing the same superscript letter are not significantly different (P≤0.05).*
Where: 1=100% wheat flour, 2= 20% wheat germ, 3= 40% wheat germ, 4= 30% inulin, 5= 40% inulin, 6= 10% chia mucilage, 7= 15% chia mucilage, 8= 20% chia mucilage, 9= mix 1 (30% inulin + 10% chia mucilage + 20% wheat germ) and 10= Mix 2 (40% inulin + 15% chia mucilage + 10% wheat germ).

compared to 82.70, which were obtained by the control sample. Thus, the replacement of wheat flour by 20 and 40% of wheat germ decreased overall acceptability scores (70.20 and 63.70, respectively). Also, adding wheat germ to Mix 1 and Mix 2 decreased the overall acceptability compared to the control sample. The mucilage gel level strongly influenced the sensory properties of the biscuit. By considering the biscuits' overall acceptability, chia mucilage gel can be considered a potential fat replacer [16].

CONCLUSION

The quality attributes, nutritional values, and physical properties of biscuits were strongly related to the ingredients of biscuit dough. Furthermore, the risk of full-fat biscuits can be reduced by replacing the added butter with 30-40% inulin or 10, 15 and 20% chia mucilage. The current study indicated that replacing the fat of the biscuit formula with 20% chia mucilage improved the overall acceptability of biscuits compared to the control sample. However, the hardness of the biscuit was increased. Inulin also showed a higher value of overall acceptability up to 30% replacement. Thus, the replacement of wheat flour by 20 and 40% of wheat germ showed lower values of sensory parameters and significantly ($P \leq 0.05$) increased protein and crude fiber content compared to the control sample.

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