Volume 9, Issue 5, 2019, 4248 - 4254 ISSN 2069-5837
Biointerface Research in Applied Chemistry
www.BiointerfaceResearch.com
https://doi.org/10.33263/BRIAC95.248254
Original Research Article Open Access Journal
Received: 11.08.2019 / Revised: 20.08.2019 / Accepted: 25.08.2019 / Published on-line: 26.08.2019

Effect of corn bran as a fat replacer on quality characteristics of low-fat mayonnaise sauce

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ABSTRACT
Background: Nowadays, obesity, hypertension and cardiovascular diseases are increasing because of using foodstuffs with high fat content. Therefore, attention has been drawn to produce low calorie foods by reducing or eliminating fat through application of fat replacers. Different levels of corn bran as a fat replacer were utilized to manufacture low-fat mayonnaise. Four treatments were prepared including control without corn bran (IZ1), low-fat with 25% corn bran (IZ2), low-fat with 50% corn bran (IZ3) and low-fat with 75% corn bran (IZ4). Finally, the effect of this replacement on chemical composition, viscosity, color, total phenolic content and sensory properties were investigated. Physicochemical analysis showed that the low-fat mayonnaise samples had higher water activity and acid value during storage and lower pH values in storage time than the full-fat samples. The apparent viscosity of samples containing corn bran increased by increasing the level of corn bran. Also, sensory evaluation indicated that IZ1 obtained the highest scores in some properties such as texture, mouth feel, viscosity and intent to purchase compared to other sample. Moreover, the lightness value (L*) of low-fat mayonnaise decreased by increasing the level of corn bran. It can be concluded that corn bran can be used in the formulation of low-fat mayonnaise as a fat replacer with acceptable physicochemical and sensory properties.

Keywords: *Mayonnaise sauce, fat replacer, physicochemical characteristics, sensory properties.*

1. INTRODUCTION

Mayonnaise is one of the oldest and common food products used around the world. It is a semi-solid oil-in-water emulsion containing 70-80% fat that is prepared by mixing of oil, egg yolk, vinegar, salt and spices and is considered as a high calorie food [1, 2]. Mayonnaise stability depends on various factors such as the amount of oil and egg yolk, viscosity, oil/water ratio, water quality, temperature and mixing method [3, 4].

In recent years, consumer awareness regarding the relation between consumption of foods with high fat content and induction of cardiovascular diseases, hypertension and obesity has encouraged the food industry to develop healthier food products with a lower level of fat [5-7]. Furthermore, fat plays a substantial role in physiochemical and sensory properties of mayonnaise because lipid phase contributes to characteristics such as texture, stability, color and flavor. Therefore, production of low-fat mayonnaise with acceptable characteristics is a great challenge [8, 9]. In this regard, various hydrocolloids such as starch, inulin, pectin, guar gum, xanthan gum have been utilized in mayonnaise formulation [8, 10].

Su *et al.* (2010), developed low fat mayonnaise consisting of xanthan gum (15 g kg^{-1}), citrus fiber (100 g kg^{-1}) and guar gum (0, 5.0, 7.5, 10.0 or 12.5 g kg^{-1}) and the results showed that 15 g kg^{-1} xanthan gum + 10 g kg^{-1} guar gum and 100 g kg^{-1} citrus fiber + 5 g kg^{-1} guar gum could be utilized in production of low fat mayonnaise and there were no significant differences in yield stress, viscosity and flow behavior index between this two samples and control [11]. Combination of three types of inulin including short, medium, and long chains (0-10%) and modified starch (0–3%) using the D-optimal design was investigated by Alimi *et al.* (2013) to produce low calorie mayonnaise. They found that increases in starch content (≥ 1.5%), inulin chain length, and concentration of long-chain inulin (≥5%) resulted in an improvement in the elastic properties of the emulsion and more resistance against deformation [12].

Aslanzadeh *et al.* (2012), studied the effect of modified wheat bran (1, 2 and 3%) as a fat replacer on the rheological properties of low fat mayonnaise. They observed that the treatments with 1% modified wheat bran had the most similar behavior to the blank sample [13].

Inulin is widely used in the food industry for various purposes such as gel forming, low calorie sweetener and as dietary fiber [14]. Mostly, inulin is utilized as fat replacer and various studies examined addition of inulin to decrease fat level in different food products such as cheese, milk, yogurt and ice cream, meat and poultry products, bread, biscuits and cereal [15-19].

The ability of inulin in fat substituting goes back to its particle gel properties. It can be used as a fat replacer only in food systems that water is a continuous phase. Compared to gel formation, less inulin is used as fat replace and substituting fat depends on number of inulin particles in the food matrix which can be affected by level of inulin, type of inulin and shearing forces [20]. Xanthan is a thickening and stabilizing agent that increase the viscosity and reduces syneresis in mayonnaise which is caused by reducing the amount of fat [21].

The viscosity of xanthan solutions is not affected by pH and only extreme pH conditions (pH 11–12, pH 1–2) can change viscosity of xanthan. Additionally, although viscosity of xanthan solution decreases by increasing temperature, the viscosity is recovered by cooling. Therefore, rheological behavior of xanthan contributes to creation of good sensory qualities such as including mouth-feel and flavor release in foods and solution [20, 22]. Furthermore, various dietary fibers derived from cereals, have been added to different food products to partially substitute fat content and improve the rheological properties and stability [23]. Corn bran which is a dietary fiber, is a by-product of corn milling and has high water-holding capacity. Corn bran as dietary fiber can bind faecal mutagen human digestive track and shows protective effect against these mutagens [24].

Yadav *et al*. (2016) studied production of dietary fibre enriched chicken sausages by adding corn bran, dried apple and tomato pomace at 3, 6 and 9 percent levels. The results showed that the samples containing 3 percent corn bran and 6 percent dried apple pomace and 6 percent dried tomato pomace had acceptable physicochemical, sensory and microbial properties [25].

To the best our knowledge, using corn bran in formulation of mayonnaise has not been explored before and in this study, low-fat mayonnaise was prepared by replacing a part of fat content by different levels of corn bran and effect of this replacement on chemical composition, viscosity, color, total phenolic content and sensory were investigated.

2. MATERIALS AND METHODS

2.1. Materials.

The ingredients used in mayonnaise formulation included: soybean oil (Vioni, Iran), vinegar (Varda, Iran), salt (Golha, Iran), sugar (Shahroud, Iran), eggs, long-chain inulin (Frutafit Tex, Sensus, Netherlands), corn bran (Z-trim, Mundelein, US) and xanthan (Alpha chemika, Mumbai, India). Different formulations of low-fat mayonnaise are illustrated in Table 1.

Table 1. Formulations of full fat and low-fat mayonnaise.

Low-fat samples Ingredients	IZ1	IZ2	IZ3	IZ4
Vegetable oil	74	55.5	37	18.5
Sugar	5	5	5	5
Vinegar	11	11	11	11
Xanthan gum	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5
Inulin	0.5	0.5	0.5	0.5
Mustard powder	0.5	0.5	0.5	0.5
Egg	8	8	8	8
Water	0	16	32	48
Corn bran	0	2.5	5	7.5

2.2. Mayonnaise preparation.

To prepare different mayonnaises, first, inulin, xanthan, corn bran, water, sugar, mustard powder, whole egg and vinegar were mixed (Model 584, Tefal, France) in high speed for 3 minutes. After that, oil was gradually added into mixture and stirred at 6000 rpm for 6 min until the emulsion system was established. Finally, the mixture of all ingredients was blended at 1500 rpm for a further 5 min. All of the prepared samples were kept in the refrigerator at 4°C until the physicochemical and sensory analysis.

2.3. Composition analysis.

Moisture and ash content were determined according to AOAC official methods 950.46 and 920.153, respectively [26]. A_w was measured using Novasina LabSwift water activity meter (Switzerland) at a temperature of 25°C. Fat content was determined using Soxhlet apparatus according to AOAC official methods 963.15 [27]. pH was measured using pH-meter (Lutron-212, China) and acidity was determined by titration of sample with 0.1 N NaOH according to the equation (1) and the results were reported according to % acetic acid after 1, 30, 60 and 90 days.

$$\text{Acidity (\% acetic acid)} = \frac{0.006 \times a \times 100}{s} \quad (1)$$

a = the volume of NaOH; b = the weight of sample (10-15 g)

2.4. Viscosity measurement.

Apparent viscosity of samples was measured by programmable viscometer of Brookfield Engineering model RV-DV (Laboratories. Inc. USA) equipped with spindle No. 7 at room temperature (25 °C). 500 g of sample was placed in 600 mL beaker and apparent viscosity was measured at rotating speed of 100 rpm. For each sample, three measurements were taken and their means were reported.

2.5. Determination of Total phenolic compounds.

Total phenol content (TPC) was measured by Folin-Ciocâlteu method [28]. 0.2 mL of sample was mixed with 0.05 mL Folin-Ciocâlteu reagent, 0.5 mL 20% Na_2CO_3 and 4.25 mL deionized water. Then the mixture was allowed to stand for 30 min at room temperature before the absorbance were measured at 760 nm spectrophotometrically (CECILL-CE 7200). TPC values were determined from a calibration curve prepared with a series of gallic acid standards (0, 5, 10, 15, 20, 30 and 40 mg/L) that reacted the same as the samples with Folin-Ciocâlteu reagent. The final results were expressed as gallic acid equivalents (mg GAE per 100 mL).

2.6. Color measurement.

Lightness (L*), redness (a*) and yellowness (b*) values of the samples were measured using HunterLab (Chroma Meter CR-410). The positive and negative values of a* showed the magnitude of reddish and greenish of samples, respectively. On the other hand, a positive value of b* indicates yellowish and its negative indicates bluish of the mayonnaise samples.

2.7. Sensory analysis.

A panel of 15 assessors evaluated the sensory properties according to their previous experience in mayonnaise evaluation. The sensory characteristics included color, flavor, appearance, texture, mouthfeel, consistency, overall acceptability and intent to purchase. Each of these parameters was scored on a five-point scale: 0= the lowest score and 5: the highest score. The samples were numbered by three-digit coding, presented to assessors and between each samples, they were instructed to rinse their mouths. All sessions were carried out in a sensory laboratory with separate booths.

2.8. Statistical analysis.

The experiments were performed in triplicates. Analysis of variance (ANOVA) was performed using the Duncan's multiplerange test to compare treatment means. The SPSS V 16 was used and the significance was defined at $P< 0.05$.

3. RESULTS

3.1. Chemical composition.

The composition analysis of control and low-fat mayonnaise samples are demonstrated in Table 2. As expected, the fat content was affected by the addition of corn bran and there were significant differences among the samples in term of fat content. The highest and lowest levels of fat was related to control and IZ4, respectively. Furthermore, the results showed that by increasing corn bran, water activity and moisture values increased. The lowest water activity was observed in the control sample that significantly differed from samples containing corn bran. Although an increasing manner was observed in water activity in the low-fat samples by increasing corn bran content, there were no significant differences among treated samples in term of water activity. Similarly, various studies indicated that water activity value increased by increasing the percentage of fat replacers [11, 29, 30]. Water has a key role in function of carbohydrate-based fat replacer by forming gel-like structure through interaction with fat replacers that improve texture of low fat mayonnaise [30]. Therefore, the increase of water activity can be ascribed to the ability of carbohydrate-based fat replacers to bind and hold water in their structure through hydrogen bind [29, 31]. Moreover, El-Bostany *et al*. (2011) found that using potato powder as a fat replacer in production of low-calorie mayonnaise resulted in a remarkable increase in moisture content of low-fat samples in comparison with high-fat mayonnaise. They indicated that this increase could be attributed to carbohydrate nature of potato powder [32]. As shown in Table 2, there was no significant difference in respect of ash content in low-fat and control samples. However, by increasing the level of corn bran, ash content was enhanced in low-fat samples. Similarly, Su *et al*. (2010) studied the application of carbohydrate-based fat replacers in production of low-fat mayonnaise and found that although the use of a fat substitute resulted in a slight increase in ash content, this increase was not significant [11]. Furthermore, Hosseinvand and Sohrabvandi (2016) investigated the effect of pectin, inulin and β-glucan as fat substitutes on physicochemical properties of reduced-fat mustard sauce and found that there were no significant differences between the control and low-fat samples in term of ash content [29].

Table 2. Chemical composition of full-fat and low-fat mayonnaise samples.

Samples	Fat	Moisture	Ash	Water activity
IZ1	75.14 ± 0.14 [a]	14.01±0.65 [d]	0.848±0.1 [a]	0.922±0.14 [b]
IZ2	56.71±0.33 [b]	33.18±0.32 [c]	0.851±0.19 [a]	0.939±0.17 [a]
IZ3	38.11±0.98 [c]	51.02±0.22 [b]	0.852±0.09 [a]	0.942±0.33 [a]
IZ4	19.54±0.11 [d]	70.66±0.25 [a]	0.854±0.88 [a]	0.949±0.66 [a]

IZ1: control, IZ2: 2.5% corn bran, IZ3: 5% corn bran, IZ2: 7.5% corn bran

Same letters in each parameter show no significant difference (P>0.05). Data are expressed as mean ± standard deviation

3.2. pH and titratable acidity.

According to Iranian National Standard [33], pH and acidity of mayonnaise sauce should be lower than 4.1 and in the range of 0.65-0.85, respectively. The results of pH measurement during storage are shown in Figure 1. As can be seen, there was no significant difference in pH values of control and low-fat samples which were prepared by corn bran and all samples were acceptable regarding the standard range. Addition of β-glucan prepared from spent brewer's yeast to mayonnaise formulations as a fat replacer was investigated by Worrasinchai *et al*. (2006). They reported that there were no significant differences in pH values between control and low-fat mayonnaise [34]. Similar results were obtained by Choonhahirun, (2008) and Johary *et al*. (2015) [35, 36]. Furthermore, in this study, pH values showed a gradual decreasing manner in all mayonnaise samples during 90 days storage and pH of control sample was lower than low-fat sample at the end of storage. This fluctuation could be attributed to the attractive and repulsive forces between the polar and non-polar groups of polysaccharides and protein [37]. The higher pH values of low-fat samples in comparison with control at the end of the storage was related to the dilution of the vinegar (acetic acid) in the low fat samples [29, 30, 38]. The acidity of the samples during 90 days storage are also shown in Figure 2. Based on the value that has been set by Iranian National Standard, acidity must be more than 0.6 and all formulation samples were in accordance with the standard limit. Acidity gradually increased during the storage period as pH decreased. It has been reported that formation of carboxylic groups due to the breakdown of ester groups in the structure of hydrocolloids has contributed to pH decrease and acidity increase. Furthermore, due to the presence of fat replacer in the low-fat mayonnaise and higher water content, it seems that acid tolerant microorganisms such as lactic acid bacteria might grow and due to the activity of lactic acid bacteria, the drop in pH may occur during storage [36, 39, 40]. Although pH and acidity had a slight change, the values were in the range established by Iranian National Standard [33].

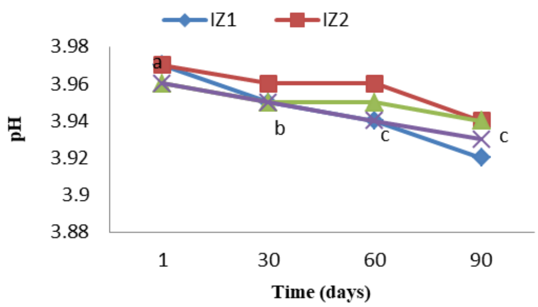

Figure 1. pH changes in mayonnaise samples containing corn bran during storage.

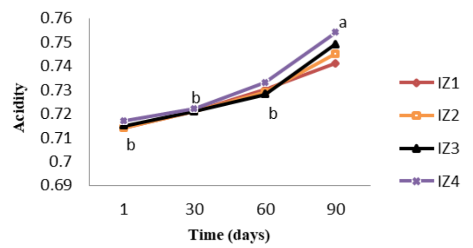

Figure 2. Acidity change in mayonnaise samples containing corn bran during storage.

3.3. Total phenolic content.

Since phenolic compounds have antioxidant and antimicrobial potential, it has been suggested to utilize these valuable components in formulation of various foods especially functional food products [41]. As shown in Figure 3, the highest total phenolic content was observed in IZ4 followed by IZ3. The control sample had the lowest total phenolic compounds and there was no significant difference between control and IZ1. In a study by Johary *et al*. (2015), the highest and the lowest phenolic content were reported in mayonnaise samples containing 1.5% tragacanth gum + 4.6% basil seed gum and control samples. They also indicated that using sesame seed oil in formulation of low-fat sauces resulted in an increase in phenolic content compared to full-fat sauce [36]. In this study, corn bran has been applied as a fat replacer in formulation of mayonnaise. It has been reported that corn bran is one of the most important sources of phenolic acids (PAs) such as ferulic acid; p-coumaric acid; di-FA, diferulic acids [42]. As can be seen in Figure 3, by increasing the amount of corn bran, total phenolic content increased. This could be justified due to the increase in the amount of ferulic acid; p-coumaric acid and di-FA, diferulic acids in low-fat samples.

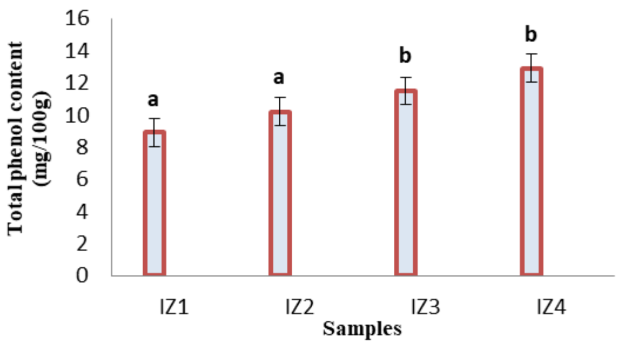

Figure 3. Total phenolic compounds of full fat and low fat mayonnaise samples.

3.4. Viscosity measurement.

Viscosity is one of the most important and effective factors in consumer acceptance of mayonnaise sauce. Figure 4 indicates the viscosity of samples. Although the highest viscosity was observed in IZ4 (12339 cp), there was no significant difference between low-fat samples containing various amount of corn bran. Furthermore, the viscosity of the control sample (IZ1) was significantly lower than low-fat samples. It has been reported that by increasing gum concentration, viscosity of the model mayonnaise increased [10]. Probably, entrapment of oil droplets in the gel-like structure formed by hydrocolloids slows down the movement of oil droplets resulting in an increase of viscosity [43]. Therefore, it could be concluded that higher viscosity in the mayonnaise samples containing corn bran may be due to the dietary fiber and polysaccharide that present in corn bran. Similarly, it has been reported by Johary *et al*. (2015) and Liu *et al*. (2007) that addition of hydrocolloids increased the viscosity and consistency of low-fat mayonnaise [36, 44]. Furthermore, Nikzade *et al*. (2012) reported that using a mixture of xanthan gum, guar gum and mono-diglyceride compared to using them individually was more effective in increasing firmness, adhesiveness, and adhesive force values in low-fat mayonnaise [1]. Therefore, it is important to choose suitable and exact amount of fat replacer especially carbohydrate-based and hydrocolloids to achieve good textural properties due to the increase in viscosity.

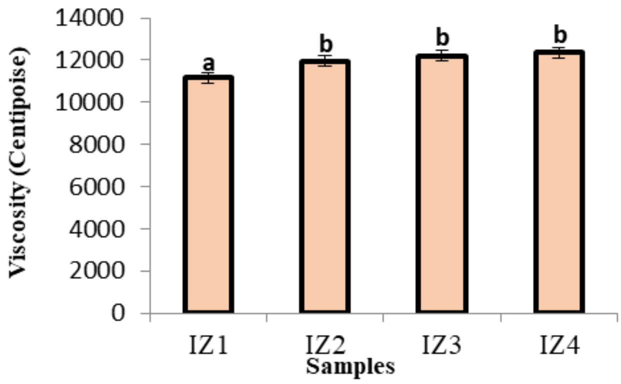

Figure 4. Apparent viscosity of full fat and low fat mayonnaise samples.

3.5. Color measurement.

Color parameters, especially lightness (L^* value) play an important role in consumer acceptance. The results of L^*, a^*, and b^*values of the mayonnaise samples are given in Table 3. The results showed that addition of corn bran had a significant effect on color attributes in mayonnaise samples. The highest L^* was related to the control sample (IZ1) and by increasing the amount of corn bran, L^* was reduced. Due to the pale yellow color of corn bran, L^* value was affected and there were significant differences in term of L^* value among control and sample containing corn bran. Similarly, Johary *et al*. (2015) found lower L^* value of low-fat mayonnaise compared to full-fat mayonnaise. They indicated that reduction of oil content resulted in a darker appearance in low-fat samples [36]. In contrast, Su *et al*. (2010) reported that low-fat mayonnaise had higher L^* value than control. [11]. Furthermore, Hosseinvand and Sohrabvandi (2016) stated that utilization of inulin and pectin in formulation of low-fat mustard sauce increased L^* value, while β-glucan addition decreased L^* value [29]. It has been stated by Chantrapornchai *et al*. (1999) that by decreasing size diameter and therefore, increasing light scattering, brightness of emulsion increased [45]. Therefore, by addition of various compound particularly hydrocolloids and reducing oil, L^* value may increase or decrease. Worrasinchai *et al*. (2006) studied addition of β-glucan (25, 50 and 70 %) in the production of low-fat mayonnaise. The results showed that the sample containing 25 and 50% β-glucan had lower L^* value in comparison with full-fat mayonnaise without β-glucan. On the other hand, the sample containing 50% β-glucan due to its much smaller droplet size had the highest L^* value even more than the control [34]. According to the Table 3, it could be understood that there is no significant difference in all samples regarding a^* value, while b^* value increased by increasing corn bran content. It seems that yellow color of corn bran participates in the presence of yellow color.

Table 3. Color measurements of full fat and low fat mayonnaise samples.

sample	L*	a*	b*
IZ1	81.16 ± 0.15^a	4.11 ± 0.15^a	5.33 ± 0.33^c
IZ2	79.10 ± 0.25^b	3.94 ± 0.32^a	5.39 ± 0.35^b
IZ3	77 ± 0.32^b	4.04 ± 0.15^a	5.44 ± 0.98^b
IZ4	74.29 ± 0.17^b	3.99 ± 0.66^a	5.56 ± 0.06^a

IZ1: control, IZ2: 2.5% corn bran, IZ3: 5% corn bran, IZ2: 7.5% corn bran

Same letters in each parameter represent no significant difference ($P>0.05$). Data are expressed as mean ± standard deviation

3.6. Sensory evaluation.

Sensory scores of mayonnaise samples with different formulations are shown in Table 4. Appearance and color scores of low-fat samples were decreased by increasing the level of corn bran compared to control samples. Among all treatments, IZ2 obtained the highest score in some characteristics such as texture, mouthfeel, total acceptability and intention to buy the product. Regarding color, IZ1 and IZ4 obtained the highest and the lowest scores, respectively. In respect of consistency, samples containing corn bran had the highest scores that were consistent with the results of viscosity measurement. Johary *et al*. (2015) reported that the highest overall acceptability belonged to full-fat mayonnaise and the low-fat sample containing 20% sesame seed oil, 2.5% tracaganth gum and 2.5% basil seed gum. They also indicated that the in samples containing higher amount of hydrocolloids, no better texture was observed. They explained that this low score for texture might be due to the insufficient dispersion or hydration of hydrocolloids in water that creates grainy texture in the final product [36].

Furthermore, Hosseinvand and Sohrabvandi (2016) studied addition of some fat replacer pectin (25, 50 and 75%), inulin (25, 50 and 75%) and β-glucan (25, 50 and 75%) in production of low-fat mustard sauce. They mentioned that sensory attributes significantly varied in control and low-fat mustard sauces and the highest score of overall acceptability and intent to purchase was related to the control and the sample containing 25% β-glucan. They finally concluded that 25% of oil content could be substituted by all of fat replacers without having undesirable effects on sensory and texture properties [29].

Additionally Choonhahirun (2008) investigated the effect of konjac flour as a fat replacer on some physicochemical and sensory properties of Celery mayonnaise. They recognized that the greatest score for thickness, meltability and oiliness belonged to the control sample and by increasing percentage of the oil replacement, score of various sensory properties decreased [35]. Moreover, Worrasinchai et al (2008) claimed that the sensory properties of mayonnaise were only acceptable when maximum 50% of the oil content was replaced by β-glucan [34].

Table 4. Sensory evaluation of full- fat and low fat mayonnaise samples.

Sample	Color	Appearance	Taste	Texture	Mouth feel	Consistency	Overall acceptability	Intent to purchase
IZ1	4.4 ± 0.14^{a}	4.1 ± 0.55^{a}	4.1 ± 0.66^{a}	4.3 ± 0.95^{b}	4 ± 0.34^{b}	4.2 ± 0.88^{a}	4.2 ± 0.19^{a}	4.5 ± 0.35^{b}
IZ2	4.1 ± 0.18^{ab}	3.9 ± 0.32^{b}	3.8 ± 0.99^{b}	4.4 ± 0.74^{a}	4.1 ± 0.58^{a}	4.4 ± 0.37^{a}	4.2 ± 0.29^{a}	4.6 ± 0.33^{a}
IZ3	4.0 ± 0.2^{ab}	3.9 ± 0.39^{b}	3.8 ± 0.68^{b}	4.3 ± 0.33^{b}	3.9 ± 0.45^{b}	4.3 ± 0.68^{a}	3.8 ± 0.33^{ab}	4.2 ± 0.69^{b}
IZ4	3.8 ± 0.15^{ab}	3.9 ± 0.09^{b}	3.7 ± 0.37^{b}	3.9 ± 0.30^{b}	3.9 ± 0.08^{b}	4.3 ± 0.59^{a}	3.6 ± 0.33^{ab}	3.9 ± 0.22^{b}

IZ1: control, IZ2: 2.5% corn bran, IZ3: 5% corn bran, IZ2: 7.5% corn bran
Means in each factor followed by different letters are significantly different ($P < 0.05$). Data are expressed as mean ± standard deviation

4. CONCLUSIONS

This study was aimed to investigate the effect of various amount of corn bran as a fat replacer on some physicochemical and sensory properties of low-fat mayonnaise that was enriched by inulin and xanthan. The results showed that addition of corn bran increased apparent viscosity of low-fat mayonnaise in comparison with control. Furthermore, low-fat mayonnaise samples had higher water activity and acidity during storage than the full-fat sample. However, all the samples, both low-fat and high-fat samples were acceptable in term of pH and acidity according to Iranian National Standard. Based on the sensory evaluation, the sample containing 2.5% corn brand (IZ2) had the highest scores in some sensory properties such as texture, mouth feel, consistency and intent to purchase. Generally, the result of this study revealed that it is possible to use corn bran as fat replacer to produce low-fat mayonnaise sauce with acceptable physicochemical and sensory properties.

Acknowledgement

Support for this study provided by Shahid Beheshti University of Medical Sciences is gratefully acknowledged.

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