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ORIGINAL PAPER

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THE PHYSICOCHEMICAL, TEXTURE HARDNESS AND SENSORIAL PROPERTIES OF ULTRAFILTRATED LOW-FAT CHEESE CONTAINING GALACTOMANNAN AND NOVAGEL GUM

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ABSTRACT

Background. Today's demand for low-fat dairy products, especially cheeses with favorable qualitative properties such as high-fat cheese, has increased. The main goals of this research are to optimize the textural hardness properties of ultrafiltrated, low-fat cheese (7–9%), to investigate the possibility of its production with various concentrations of galactomannan and novagel (0.1–0.5%), and to assess the physicochemical, textural hardness and sensorial properties of the produced low-fat cheese in comparison with full-fat cheese.
Methods. The textural hardness of the cheeses was tested by a texture analyzer (Stable micro system TA.XT plus Texture, London, UK) equipped with a load cell of 5 kg. The pH values were measured using the pH meter and acidity of the cheese samples according to AOAC standard no. 15004 (AOAC, 1995b). The moisture content and dry matter were measured according to AOAC standard number 920.124 (AOAC, 1995a) as well. The total protein was measured according to AOAC standard no. 991.20 (AOAC, 2005). The amounts of salt and ash were measured according to AOAC (1995a) standard no. 945.46 (AOAC, 1995b), respectively.
Results. The results show that the textural hardness properties and sensorial properties of the cheese treatment containing 9% fat, 0.5% galactomannan, and 0.3% novagel are very similar to selected control samples. Meanwhile, optimization of the textural properties of low-fat cheeses via the response-surface method shows that the treatment containing 9% fat, 0.32% novagel and 0.5% galactomannan fulfills the desirable properties of a full-fat cheese up to 100% desirability.
Conclusion. The results of this research also show that by using galactomannan and novagel in the formulation of low-fat cheese, it can be produced with favorable texture textural hardness and sensorial properties close to full-fat cheese.

Keywords: ultrafiltrated low-fat cheese, novagel, galactomannan, hydrocolloid

INTRODUCTION

Cheese is a general name that refers to a large group of fermented dairy products which are produced in various tastes and shapes all over the world (Fox et al., 2004). Ultrafiltration is a type of membrane separating operation which selectively concentrates milk protein and fat. The milk ultrafiltration process causes

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the production of retentate and permeate. Permeate, which is called the passing phase or residue, contains water, lactose, soluble minerals, non-protein nitrogen, and water soluble vitamins, and the retentate, or concentrated milk, which is also called the indissoluble phase, includes casein, whey proteins, fat, and colloidal salts. Water elimination prior to the cheese making process leads to a decrease in the required syneresis rate, and whey proteins mostly remain in the clot during the cheese making process (Bylund, 1995). In the form of ultrafiltration, this type of cheese is heavily consumed during breakfast in Iran as well and, since the fat content of this product is usually high, remarkable efforts have been made in order to reduce the fat content in this important foodstuff (Madadlou et al., 2005; Rudan et al., 1999).

There is a lot of evidence to indicate a relationship between more fat consumption and an increased risk of diseases such as obesity, atherosclerosis, coronary heart disease, cancer tissue damage, and types of distinct cancers. With regard to the aforementioned issues and increased awareness of people towards fat consumption, a remarkable increase has occurred in the demand for low-fat products like low-fat cheeses (Katsiari et al., 2002; Kavas et al., 2004).

Besides its nutritional value, cheese fat has a great role to play in the improvement of cheese texture and appearance. Low-fat cheese has some kinds of defects such as a rigid and elastic texture, undesirable color and taste, and poor melting quality (Mistry, 2001). Due to a decrease in fat content, the cheese protein network becomes more compressed and denser and the cheese texture becomes chewable (Romeih et al., 2002). Hence, new methods such as changes in the common methods of production, selection of subcultures, and application of fat substitutes (Katsiari et al., 2002) have been created to produce low-fat cheeses containing the properties of high-fat ones. The use of fat substitutes has proved to be the best method for improving the productivity and textural features of a low-fat cheese in different research (Madadlou et al., 2007b).

Galactomannans are natural polysaccharides obtained from the seed endosperm of some legumes which are used as gum in the food industry and some other industries (Zhang and Chen, 2013). These are very hydrophilic gums with high molecular weights and a set of polysaccharides and also some proteins which enhance viscosity through dissolving and distribution in water. Nowadays, these compounds are widely used in different industries for condensation, gel formation, film formation, foam stabilization, emulsion and dispersion, prevention of ice and sugar crystal formation, and the controlled release of tastes (Akbari et al., 2015).

Novagel is a mixture of Micro Crystalline Cellulose (MCC) and guar gum driven from fruits and vegetables that can be used as a fat reducer in food processing (McMahon et al., 1996).

Rahimi et al. (2007) applied hydrocolloids as the fat substitute in the low-fat type of these cheese and they could decrease the textural hardness parameters and improve its texture. They used two types of hydrocolloids – gum arabic, and guar gum – as the fat substitute and next evaluated the effect of arabic gum, and guar gum on the textural properties of low fat cheese. The results showed that by reducing fat content the textural parameter values (hardness and cohesiveness) increase and the structure also compresses further. Likewise, the addition of tragacanth gum to cheese can cause an increase in the moisture content, a decrease in hardness, and an improvement of the sensory attributes (Rahimi et al., 2007). Lobato-Calleros and his colleagues (2006) added different hydrocolloids, such as pectin, carboxymethyl cellulose, and arabic gum, to cheese as an alternative to fat. In their study, the cheese containing carboxymethyl cellulose showed similar textural and rheological properties to high-fat white cheese. The determination of the best gum level in the production of low-fat cheese that represents the same characteristics as the high-fat sample requires the performance of adequate experiments, which in turn has costs and processes. Response surface method – RSM is an appropriate tool for optimizing the formulation of new products. Through the application of this method, the number of treatments, and subsequently the research, decrease remarkably (Goudarzi et al., 2015). The aim of this study was to evaluate the physicochemical, textural hardness and sensorial properties of ultrafiltrated low-fat cheese containing galactomannan and novagel gum.

MATERIALS AND METHODS

Materials

To prepare the cheese, retentate powder (80% protein, 9% lactose, 1% fat and 7% ash), reconstituted retentate (6% fat and 30% solid) and butter (proteins: 0.49%, water: 16%, fat: 82%), were purchased from Pegah (Tehran, Iran). Novagel® 110 was purchased from Food Chem (Shanghai, China) and galactomannan from Veer (Surat Gujarat, India). Standard cheese rennet (single strength fermentation-derived chymosin) and mesophilic lactic starter cultures (R-704) were purchased from Chr. Hansen (Milwaukee, USA) and salt was purchased from Golha, (Tehran, Iran). The chemical materials used for the tests were comprised of boric acid, sodium hydroxide 0.1 normal, nitric acid, potassium permanganate, mercuric oxide, oxalic acid, potassium sulfate (K2SO4), sulfuric acid, ammonium thiocyanate, normal silver nitrate 0.1, and phenolphthalein from Merck (Germany co.).

Methods

Preparation of ultrafiltrated cheese. The experimental cheese samples were prepared by mixing reconstituted retentate (200 g), 45°C water (556 g), and retentate powder (244 g) in a pasteurizer at a temperature of 50°C. Then, to adjust the final fat level in the ultrafiltrated cheese (7%, 8%, 9%, and 22%) butter was used and again mixed well at a temperature of 60°C until the butter was fully melted. After that, different concentrations of novagel gum and galactomannan were weighed and added to the mixture based on the treatments in Table 1. The mixture was well stirred and homogenized at a temperature of 75°C and a pressure of 90 bar using an Ultra-Turrax, IKA10, Germany T-Basic model homogenizer, and then pasteurized at a temperature of 78°C for 5 minutes in a pasteurizer (VB-1820J, Faraz Electronic, Iran). After pasteurization, the temperature of the milk was reduced to 34°C and 0.03% mesophilic lactic starter cultures and 0.05% rennet enzyme were added to the mixture, then the mixture was stirred well and poured into 100 g containers. When the curds formed, 2% salt was added. Then thermal sealing was carried out using polypropylene laminated aluminum foil and the samples were incubated at 33°C for 24 hours before being transferred to a refrigerator at a temperature of 5°C (Rashidi et al., 2015). After 72 hours, tests were repeated three times.

Textural profile analysis (TPA). The textural hardness of the cheeses was tested by a texture analyzer (Stable micro system TA.XT plus Texture, London, UK) equipped with a load cell of 5 kg. To do this experiment, a piece of cheese of the same dimensions was placed in the device and pressed twice by a pressing probe. Imitating human textural perception, the first and second pressures simulated the first and second stages of human biting. In this method, the indexes of hardness were investigated (Rolle et al., 2012). To conduct the tests, a 3.6 mm diameter cylindrical probe with a progressive forehead was used at a temperature of 6°C when cutting and an ambient temperature (25°C) during testing, with a sample size of 1×1 cm and a pre-test of 30 mm/min.

Physicochemical tests. The pH value was measured using a pH meter and the acidity of the cheese samples was assessed according to AOAC standard no. 15004 (AOAC, 1995b). The moisture content and dry matter were measured according to AOAC standard number 920.124 (AOAC, 1995a) as well. The total protein was measured according to AOAC standard no. 991.20 (AOAC, 2005). The amounts of salt and ash were measured according to Wolhard (1995) and AOAC standard no. 945.46 (AOAC, 1995b), respectively.

Sensorial evaluation. The sensory evaluation of the cheese samples was done by 10 trained sensory panelists. The panelists were not lactose intolerant or allergic to dairy product. The panelists evaluated and scored the cheese samples for texture, taste, color and overall acceptability. The scoring was performed using a 5-point hedonic scale (1 = the least favorable, 5 = the most favorable; Goudarzi et al., 2015).

Design of treatments and data analysis method. To design the treatments, three independent variables were used to determine the fat content of low-fat cheeses (9–7%) and different concentrations of galactomannan and novagel (0.1–0.5%) were used according to the method of RSM Box Behnken (Table 1). Therefore, 15 treatments were designed and the results of the tests compared with high-fat cheese.

Table 1. Different levels of independent variables including cheese fat content, various concentrations of galactomannan and novagel

Independent variable %	Content		
	1+	0	1–
Fat	9 (C)	8 (B)	7 (A)
Novagel	0.5	0.3	0.1
Galactomannan	0.5	0.3	0.1

The results of the tests on the textural and sensorial properties of the low-fat cheese samples produced were analyzed using the one-way Anova Tukey method, and compared with the control sample. To achieve the best formulation of low-fat cheeses with textural characteristics like those in the control sample, single and multiple optimization was carried out using RSM Box Behnken software. Then, the discovered textural properties of the full-fat cheese samples were regarded as the target. All results were analyzed in Minitab 16 software.

RESULTS AND DISCUSSION

Physicochemical results

Table 2 shows the physicochemical properties of low-fat ultrafiltration cheese containing various concentrations of galactomannan, novagel and the control sample.

Investigation of the effects of fat, novagel and galactomannan on the pH and acidity of ultrafiltrated low-fat cheese

The results presented in Table 2 show that reducing the amount of fat leads to a decrease in pH and acidity. It was seen that the control sample had the highest pH (4.985) and the lowest acidity (0.805), while A_2 (containing 7% fat and 0.3% galactomannan and 0.1% novagel) had the lowest pH (4.810) and the highest acidity.

Using galactomannan and novagel gum has a significant effect on pH and acidity variations, which could be due to the nature of the pH of the consumable gum used in this study. The pH measured for galactomannans and novagel were 7.41 and 3.5, respectively.

On the other hand, by increasing the concentration of hydrocolloids, the moisture content of the cheeses increased and, as a result, the function of chymosin also increased (Zalazara et al., 2002), this lead to an intensification of proteolysis and a release of acidic carboxylic groups. This in turn increased the acidity, which caused a reduction in pH.

Azarnia et al. (1997) reported that increasing moisture accelerates cheese lipolysis, which leads to an increase in fatty acid production and finally a decrease in pH and increase in acidity. The results of the low-fat cheese samples of C_1 (0.3% galactomannan and 0.1% novagel), C_2 (0.5% galactomannan and 0.3% novagel) and C_4 (0.3% galactomannan and 0.5% novagel), all of which contained 9% fat, were not significantly different from the control sample ($P > 0.05$).

Confirming the results of this research, Ghanbari Shandi et al. (2011) also found that increasing concentrations of xanthan gum lead to an increase in acidity and a decrease in pH in reduced fat samples. Aminifar et al. (2014) have also observed a lower pH in lighvan cheeses containing 0.02% tragacanth gum compared to those without tragacanth gum, on the first day of sample production.

Cooke et al. (2013) reported a much lower decrease in the pH of full-fat cheddar cheese than low-fat samples during the production period. The research argues that, in low-fat samples or in samples containing hydrocolloids, the moisture-to-lactose ratio is higher than other samples, therefore it is easier for lactose to access lactic acid bacteria and, as a result, an increase in lactic acid and a decrease in pH occurs. Of course, it is worth mentioning that compounds created by proteolysis and lipolysis can play a role in changes of pH.

To optimize the characteristics of ultrafiltrated Iranian white cheese with a low-fat content, Rustamabadi et al. (2017) reported that some fat substitutes have reduced a fat content without a significant effect on pH. Therefore, for similar cases, decreasing the amount of fat leads to an increase in the moisture content, the amount of soluble chymosin, and the ratio of soluble protein to the whole. This in turn results in an increase in carboxylic acid groups and the conversion of lactose to lactate and, finally, a decrease in pH factors (Azarnia et al., 1997; Rahimi et al., 2007). On the other hand, decreasing the fat content leads to a decrease in

Table 2. Physicochemical properties of low-fat ultrafiltration cheese containing various concentrations of galactomannan, novagel and control sample

Sample codes	Cheese fat %	Galacto-mannan %	Novagel %	pH	Acidity % acid lactic	Protein %	Ash %	Moisture %	Dry matter %	Salt %
B_1	8	0.3	0.3	4.95 ± 0.02^{abc}	0.83 ± 0.00^{bcd}	9.58 ± 0.00^{e}	4.91 ± 0.04^{abc}	69.33 ± 0.04^{cde}	30.66 ± 0.04^{a}	1.92 ± 0.01^{abc}
A_2	7	0.3	0.1	4.81 ± 0.01^{d}	0.85 ± 0.00^{a}	10.34 ± 0.05^{bcd}	4.85 ± 0.00^{abcd}	70.94 ± 0.06^{a}	29.05 ± 0.06^{a}	1.86 ± 0.08^{c}
B_5	8	0.5	0.1	4.89 ± 0.00^{Bcd}	0.84 ± 0.00^{abc}	9.73 ± 0.05^{de}	4.89 ± 0.09^{abc}	69.56 ± 0.03^{bc}	30.60 ± 0.03^{a}	1.88 ± 0.01^{bc}
B_2	8	0.3	0.3	4.91 ± 0.01^{abc}	0.83 ± 0.00^{a}	9.75 ± 0.049^{de}	4.86 ± 0.00^{abcd}	69.54 ± 0.02^{c}	30.46 ± 0.04^{a}	1.92 ± 0.01^{abc}
A_4	7	0.5	0.3	4.84 ± 0.01^{cd}	0.85 ± 0.00^{ab}	10.44 ± 0.05^{b}	4.91 ± 0.00^{ab}	70.59 ± 0.00^{a}	29.40 ± 0.00^{a}	1.86 ± 0.04^{c}
C_2	9	0.5	0.3	4.98 ± 0.02^{a}	0.81 ± 0.00^{fgh}	9.46 ± 0.049^{e}	4.92 ± 0.00^{ab}	68.96 ± 0.05^{e}	31.54 ± 0.33^{a}	1.96 ± 0.02^{ab}
A_1	7	0.3	0.5	4.86 ± 0.02^{bcd}	0.84 ± 0.00^{abc}	10.47 ± 0.03^{a}	4.91 ± 0.01^{ab}	70.97 ± 0.03^{a}	29.02 ± 0.03^{a}	1.88 ± 0.01^{bc}
C_1	9	0.3	0.1	4.95 ± 0.04^{abc}	0.81 ± 0.00^{efgh}	9.44 ± 0.06^{e}	4.86 ± 0.00^{abcd}	68.40 ± 0.13^{f}	31.54 ± 0.76^{a}	1.95 ± 0.02^{abc}
B_4	8	0.1	0.1	4.86 ± 0.03^{cd}	0.84 ± 0.00^{abc}	9.60 ± 0.01^{e}	4.84 ± 0.07^{cd}	69.10 ± 0.14^{de}	30.05 ± 0.07^{a}	1.89 ± 0.01^{abc}
B_3	8	0.1	0.5	4.92 ± 0.02^{abc}	0.83 ± 0.00^{cdef}	9.84 ± 0.04^{cde}	4.85 ± 0.00^{abcd}	69.41 ± 0.14^{cd}	30.58 ± 0.12^{a}	1.94 ± 0.02^{abc}
B_7	8	0.3	0.3	4.90 ± 0.01^{abcd}	0.83 ± 0.00^{a}	9.72 ± 0.04^{de}	4.87 ± 0.07^{abcd}	69.39 ± 0.03^{cd}	30.45 ± 0.07^{a}	1.91 ± 0.02^{abc}
C_3	9	0.1	0.3	4.98 ± 0.02^{a}	0.82 ± 0.00^{defg}	9.41 ± 0.03^{e}	4.95 ± 0.00^{ab}	68.90 ± 0.00^{e}	31.59 ± 0.13^{a}	1.90 ± 0.08^{ab}
B_6	8	0.5	0.5	4.91 ± 0.02^{abc}	0.83 ± 0.00^{cde}	10.18 ± 0.08^{cd}	4.93 ± 0.02^{abc}	69.95 ± 0.07^{b}	30.90 ± 0.14^{a}	1.94 ± 0.02^{abc}
C_4	9	0.3	0.5	4.94 ± 0.04^{ab}	0.81 ± 0.00^{gh}	9.45 ± 0.04^{e}	4.90 ± 0.00^{abc}	68.90 ± 0.07^{e}	31.59 ± 0.13^{a}	1.97 ± 0.02^{ab}
A_3	7	0.1	0.3	4.83 ± 0.02^{bcd}	0.85 ± 0.00^{a}	10.41 ± 0.58^{bc}	4.86 ± 0.00^{abcd}	70.62 ± 0.06^{a}	29.37 ± 0.064^{a}	1.86 ± 0.01^{c}
D	23	0	0	4.98 ± 0.00^{a}	0.80 ± 0.07^{h}	9.35 ± 0.04^{e}	4.82 ± 0.00^{d}	66.46 ± 0.14^{g}	33.54 ± 0.05^{a}	1.98 ± 0.01^{a}

The results are given as mean values ±SD.
Different letters indicate a significant difference in each column.
D – control sample: prepared with 23% fat and no hydrocolloids.

the moisture to protein ratio, followed by a decrease in proteolysis, production rates and pH variation (Rudan et al., 1999).

Fenelon at al. (2000) reported that increasing the pH during the low-fat cheese production process may lead to a decrease in the amount of moisture in solids without fat, as well as the ratio of lactate to protein. Rahimi et al. (2007) used tragacanth gum as a fat replacer in low-fat cheese production and found that pH did not change when the gum was added.

Nateghi et al. (2012) investigated the effects of sodium caseinate and xanthan gum as a fat substitute on low-fat cheddar cheese and found that pH and acidity did not change with the addition of sodium caseinate and xanthan. In other words, if the gum does not induce acidification, it will not affect the acidity or the pH of the cheese (Lobato-Calleros et al., 2001).

The effects of fat, novagel and galactomannan on ultrafiltrated low-fat cheese protein

Table 2 shows that different levels of fat, novagel and galactomannan have a significant effect on the level of protein in the tested treatments ($p \geq 0.05$). The results show that by decreasing the fat and increasing the amount of gum, the protein content of the tested treatments increased. The lowest protein after the control sample (9.355%) belongs to sample C_3, which contained 9% fat, 0.1% galactomannan, and 0.3% novagel, which is not statistically different from the control ($P > 0.05$). The highest protein content (10.475%) belongs to A_1-code of the low-fat cheese sample containing 7% fat, 0.3% galactomannan, and 0.5% novagel, which is statistically different from the control sample ($P \leq 0.05$). In low-fat cheeses, the cheese dry matter increases the contribution of protein. The protein content in the low-fat cheese samples was higher than in the full-fat control cheese sample. Since milk proteins are hydrophilic (Danesh et al., 2016), less hydration was observed in the low-fat samples than in the full-fat ones.

The results show that the protein content in cheese samples with an identical fat content, but a higher amount of gum is slightly higher due to the presence of protein in 4.03% galactomannan and 53% novagel. In addition, the increase in protein, which is induced by the increase in galactomannan and novagel, may be due to electrostatic contact between the gum and milk proteins, which prevents the protein from being wasted and thus increases its amount (Mohammadzadeh Milani et al., 2017). By decreasing the fat content, the concentration of protein increases in the matrix, and the interconnection of casein-protein increases. This leads to texture congestion and may increase the amount of protein in fat-substituted cheeses due to increased porosity in the protein structure. This is due to the fat reduction and increase in the links created via the protein-carbohydrate-matrix leading to the encapsulation of water and establishing of a linkage within the protein matrix (Madadlou et al., 2005; Mistry, 2001; Mistry et al., 1996). Nateghi et al. (2012) used xanthan and sodium caseinate to produce low-fat cheddar cheese. The results show that by decreasing the fat content of cheese, the protein content is significantly increased (Nateghi et al., 2012). Esperan et al. (2011) investigated the effects of carrageenan hydrocolloid, glucono delta-lactone, and calcium chloride on the properties of soy cheese (tofu). Carrageenan hydrocolloids probably form a good gelatinous network in the texture of the final product, holding more water in the final tofu structure and reducing the amount of water lost during compression, and consequently, increasing the weight and protein content of the product (Braga et al., 2006; Villaudy et al., 1990).

The effects of fat, novagel and galactomannan on ultrafiltrated low-fat cheese ash

According to the obtained results, the effects of different levels of fat, novagel, and galactomannan on the changes in ash in the tested treatments was significant ($P \leq 0.05$). According to the results in Table 2, the amount of ash increased significantly with a decrease in fat and an increase in the concentration of fat substitutes. The lowest amount of ash (4.825%) belonged to the control sample and the highest one (4.935%) belonged to the low-fat B_6 (containing 8% fat and 0.5% galactomannan and 0.5% novagel). The aforementioned results indicate the direct effects of novagel and galactomannan on the increased ash due to the ash contained in the same hydrocolloids (0.74% galactomannan ash and 2% novagel). Mohammadzadeh Milani et al. (2017) investigated the effects of tragacanth gum on the physicochemical properties of lighvan cheese during the production period. They observed that the gum and maintenance period cause an increase in ash samples, which is similar to the results obtained by this research.

The effects of fat, novagel and galactomannan on ultrafiltrated low-fat cheese moisture

Table 2 shows that the effects of different levels of fat, novagel, and galactomannan on the moisture variations of the tested treatments was significant ($P \leq 0.05$).

According to the obtained results, by decreasing the fat content and increasing the concentration of galactomannan and novagel, the moisture content increased in the tested treatments. Therefore, as it is seen, the highest moisture content (70.975%) belonged to the low-fat A_1 code containing 7% fat, 0.3% galactomannan and 0.5% novagel and the lowest amount of moisture after the control sample (68.405%) belonged to sample C_1 (containing 9% fat, 0.3% galactomannan and 0.1% novagel), which is statistically significantly different from the control sample ($P \leq 0.05$). Due to the fact that carbohydrate-based fat alternatives have a higher water absorption (because of their open-electron structure), the carbohydrate-matrix is compressed. This in turn leads to an increase in moisture content in cheeses containing fatty substitutes in comparison to low and full-fat control samples (Bench, 2007; Drake et al., 1999; Ghanbari Shandi et al., 2011). It is worth mentioning that both the hydrocolloids used in this study are hydrophilic and have the moisture content: galactomannan 9.20% and 12% novagel. Therefore, one can expect that their concentration in the treatments had the highest level, which is significantly more than the control sample.

Madadlou et al. (2007a) reported that low-fat cheeses containing gums have a higher moisture content than those of low-fat cheeses. This property was due to the bonding properties of these gums. Confirming the results of this study, Romeih et al. (2002) stated that the cheese's moisture content has a negative correlation with the amount of milk fat used for cheese making.

Cardarelli et al. (2008) found that inulin and oligofructose increase the amount of moisture in petit-puisse cheese. Cooke et al. (2013) investigated the effects of tragacanth gum on the rheological, functional and sensorial properties of cheddar full and semi-fat cheeses during production and showed that adding gum increases the moisture content and moisture-to-protein ratio.

Kurultay et al. (2000) investigated the effects of using carboxymethyl cellulose, gelatin and guar gum on physicochemical and efficiency of Kashar cheese. The results showed that using carboxymethyl cellulose and gelatin increase the moisture content and efficiency.

Effects of fat, novagel and galactomannan on dry material of ultrafiltrated low-fat cheese

According to the obtained results, by increasing the amount of cheese fat there is a slight increase in the amount of dry material of the tested treatments. This caused the low-fat C_4 sample (31.595%) containing 9% fat, 0.3% galactomannan and 0.5% novagel to have the highest amount of dry material after the control sample. Sample A_1 containing 7% fat and 0.3% galactomannan and 0.5% novagel had the lowest amount of dry material (29.025%). This difference is not statistically significant from the control sample.

In accordance with the results obtained by Nebizadeh et al. (2016) the effects of tragacanth gum and initiator of exopolysaccharides on the qualitative, textural and microstructural properties of cheddar cheese are significant. This study showed that the treatments containing tragacanth gum had the lowest dry matter and the highest amount of salt. The reason for this is attributed to the absorption of water by tragacanth gum since water is directly attached to fat substitutes (such as tragacanth) preventing it from mixing with gelatin particles (Koca and Metin, 2004). Moreover, the negative charge of tragacanth gum created a bond with positively charged caseins causing spatial stabilization (Dickinson, 1998). These conditions are likely to reduce coagulation due to the gap between casein micelles, and ultimately to reduce the hydrophobic bond between the para-casein micelles at the rendering stage. The tragacanth gum stabilizes the water, which means that a larger amount of water is kept in the initial matrix of the para-casein gel and an open-matrix protein cheese is created in the final structure (Cooke et al., 2013).

Lashgari et al. (2008) investigated the possibility of producing Iranian white cheese and the optimization of its characteristics using arabic gum and guar gum. This study found that decreasing the amount of fat always reduces the dry matter of cheese. Guar gum has a higher capacity for holding water, resulting in a delay in gelatins turning into water and, therefore, a reduction, in the dry matter ratio of the cheese.

Variation of the dry matter and moisture created by fat reduction is due to the variation in the protein content of cheese. Reducing the fat content of cheese leads to an increase in protein ratios, which, in fact, increases the water holding capacity of the casein matrix. These findings are consistent with the results of Volikakis et al. (2004).

The effects of fat content, novagel and galactomannan on changes in the ultrafiltrated low-fat cheese salt

Table 2 shows that different levels of fat, novagel and galactomannan significantly change the salt of the tested treatments ($p \geq 0.05$). The results showed that by increasing the amount of fat and gum, the salt absorption increases significantly. The lowest amount of salt (1.860%) was found in A_2 (containing 7% fat and 0.3% galactomannan and 0.1% novagel), A_3 (containing 7% fat and 0.3% galactomannan and 0.1% novagel), and A_4 (containing 7% fat and 0.5% galactomannan and 0.3% novagel). Meanwhile, the highest amount of salt absorption belonged to the control sample (1.98%) and the low-fat sample of C_4 (1.970%) containing 9% fat, 0.3% galactomannan and 0.5% novagel, respectively. There was no significant difference from the control sample ($P > 0.05$). The reason for the higher salt intake with the increased amount of fat in the treated treatments is related to the softened texture of the cheeses and better penetration of salt inside them. As a confirmation of the present study's results, Aminifar et al. (2014) stated that salt penetration is higher in cheeses with a softer texture.

Lashgari et al. (2008) investigated the characteristics of Iranian low-fat white cheese containing arabic and guar gum and reported that using guar gum increased the amount of salt in the cheese. They said that the difference in salt levels is probably due to the difference in the level of moisture; the higher the level of moisture, the more salt enters the water phase of the matrix.

A study done in 2007 investigated the effects of salt concentration on the chemical composition and texture of Iranian white cheese. The results of these tests revealed that salt-water concentration has an important effect on the chemical composition, proteolysis, structural composition, and rheological behavior of Iranian white cheese (Madadlou et al., 2007a).

In another study accomplished by Hayaloglu et al. in 2002, it was shown that the salt transferring from brine to cheese is related to cheese properties (moisture, fat and surface area) and salt water conditions (salt amount, temperature, and acidity of salt water). When reducing the concentration of salt in the cheese completely, there is an increase in proteolysis, water activity, acidity and bitterness, while on the other hand, there is a decrease in rigidity and salinity (Fitzgerald and Buckley, 1985).

Nebizadeh et al. (2016) investigated the effects of tragacanth gum and the initiator of exopolysaccharides producer on the characteristics of cheddar cheese. Since adding the tragacanth gum reduces the dry material of the samples, the moisture content will increase, thus the amount of salt will also increase significantly due to water solubility.

Hosseini et al. (2011) investigated the physicochemical properties of imitated cheeses containing guar gum and lighvan aromatic cheese. The results of chemical tests showed that increasing the amount of cheese and guar gum did not significantly increase the fat, salt or moisture content. Fadaei et al. (2012) investigated the effects of using inulin, locust bean gum, carrageenan and sodium caseinate on creamy cheese properties. The results showed that use of these hydrocolloids does not have a significant effect on the amount of salt in the cheese.

The assessment of the texture hardness alteration of the ultrafiltrated low-fat cheese containing various concentrations of galactomannan and novagel

From a sensory point of view, hardness is the required power for compressing one sample between molar teeth and, from a mechanical point of view, it is the power needed to achieve one distinct deformation (Fox et al., 2000; Gunasekaran and Mehmet, 2003).

The textural hardness results of the low-fat ultrafiltrated cheese samples containing different concentrations of galactomannan and novagel are shown in Table 3. The results in Table 3 demonstrate that, with fat reduction and the enhancement of galactomannan and novagel contents, the hardness value of cheese increases and decreases, respectively. The maximum hardness value (423.43 g) was in treatment A2 (containing 7% fat, 0.3% galactomannan, and 0.1% novagel) and the minimum value (142.49 g) was in treatment C4 (containing 9% fat, 0.3% galactomannan, and 0.5% novagel), which have a significant difference to the control. It can be said that sample C2, which contained 9%

Table 3. Investigation of hardness of low-fat ultrafiltrated cheese containing different concentrations of galactomannan, novagel and control

Sample codes	Galactomannan, %	Novagel %	Cheese fat, %	Hardness, g
B_1	0.3	0.3	8	294.62 ±4.03[g]
A_2	0.3	0.1	7	423.43 ±1.61[a]
B_5	0.5	0.1	8	319.32 ±2.76[ef]
B_2	0.3	0.3	8	296.76 ±3.04[fg]
A_4	0.5	0.3	7	374.87 ±3.93[bc]
C_2	0.5	0.3	9	188.85 ±14.15[k]
A_1	0.3	0.5	7	355.10 ±4.95[cd]
C_1	0.3	0.1	9	220.72 ±1.95[ij]
B_4	0.1	0.1	8	336.35 ±1.82[de]
B_3	0.1	0.5	8	258.91 ±3.51[h]
B_7	0.3	0.3	8	294.96 ±3.26[g]
C_3	0.1	0.3	9	214.67 ±0.57[j]
B_6	0.5	0.5	8	238.50 ±6.83[hi]
C_4	0.3	0.5	9	142.49 ±0.75[l]
A_3	0.1	0.3	7	393.35 ±1.87[b]
D	0	0	23	180.12 ±13.07[k]

The results are given as mean values ±SD.
Different letters indicate a significant difference in each column.
D – control sample: prepared with 23% fat and no hydrocolloids.

fat, 0.5% galactomannan, and 0.3% novagel has no significant difference to the control in terms of textural hardness ($P > 0.05$).

The increase in the textural hardness of the cheese through a reduction in fat content might be due to an absence of fat globules among casein particles and an increase in cheese compression. Fat globules and moisture act as the filler phase in the casein matrix and bring about the softness of cheese (Madadlou et al., 2005). Since in low-fat cheese formulation, as much as fat is reduced, it is not replaced by moisture, so the amount of filler phase in the matrix decreases and makes the network more compact (Romeih et al., 2002; Rudan et al., 1999) and, consequently, a harder texture is obtained.

Along with the acquired results of this experiment, Bryant et al. (1995) reported that through the diminution of fat in cheddar cheese, moisture content and hardness increase.

Połtorak et al. (2015) and McMahon et al. (1996) argued that fat reduction increases hardness and cheese grain drying, and also decreases the melting property. The application of fat substitutes such as gums can improve the undesirable effects of fat reduction in low-fat cheeses (Nateghi et al., 2012). The reason for a reduction in hardness by adding galactomannan and novagel gums might be associated with the higher ability of these compounds for water absorption. Therefore, water molecules along with gums imitate fat tasks in cheese and their position between protein molecules and prevent them from getting closer to each other. This results in softening the texture of low-fat cheeses (Romeih et al., 2002).

Fox et al. (2000) reported that water molecules placed between three-dimensional protein networks weaken its consistency and soften the product's texture.

In confirmation of the present research results, Ghanbari Shandi et al. (2011) produced Iranian low--fat white cheese containing xanthan gum, and reported that with the addition of xanthan gum, the amount of connected calcium micelles decreases and conversely the repulsion power between caseins increases, which leads to a weakness of the cheese structure bonds and an increased softness in the presence of gum.

Mohammadzadeh Milani et al. (2017) investigated the effects of tragacanth gum on the physicochemical and textural properties of lighvan cheese during production and showed that the hardness decreased with increased gum.

The results of the analysis of variance and modeling of the textural hardness of low-fat ultrafiltrated cheeses containing various concentrations of galactomannan and novagel

The analysis of variance for the textural hardness of low-fat ultrafiltrated cheeses containing different concentrations of galactomannan and novagel is illustrated in Table 4. The high coefficient of determination ($R^2 = 99.61\%$) indicated that the predicted model corresponded well to the experimental data. According to the analysis of variance results, the linear effects of

Table 4. Regression of hardness texture of low-fat ultrafiltrated cheeses

Hardness		
Source	*F*	*P*
Regression	142.55	0.000*
Linear	426.40	0.000*
Fat (A)	1099.25	0.000*
Novagel (B)	167.87	0.000*
Galactomannan (C)	12.07	0.018*
Square	1.05	0.447
Fat × fat (A^2)	0.38	0.564
Novagel × novagel (B^2)	2.87	0.151
Galactomannan × galactomannan (C^2)	0.00	0.972
Interaction	0.20	0.894
Fat × novagel (A × B)	0.35	0.578
Fat × galactomannan (A × C)	0.19	0.677
Novagel × Galactomannan (B × C)	0.04	0.874
Lack-of-fit	86.52	0.11
R^2	99.61%	

galactomannan, novagel, and fat are significant for the cheese sample hardness values ($P \leq 0.05$). The interaction and quadratic effects of the independent variables are not significant for the hardness variations ($P \geq 0.05$).

Equation (1) shows the polynomial model to predict the hardness (g) of low-fat cheeses containing different concentrations of fat (A), novagel (B), and galactomannan (C).

$$Y\,(g) = 295.447 - 97.502A - 38.103B - \\ - 10.218C - 2.673A^2 - 7.338B^2 + 0.162C^2 - \\ - 2.476AB - 1.835AC - 0.845BC$$

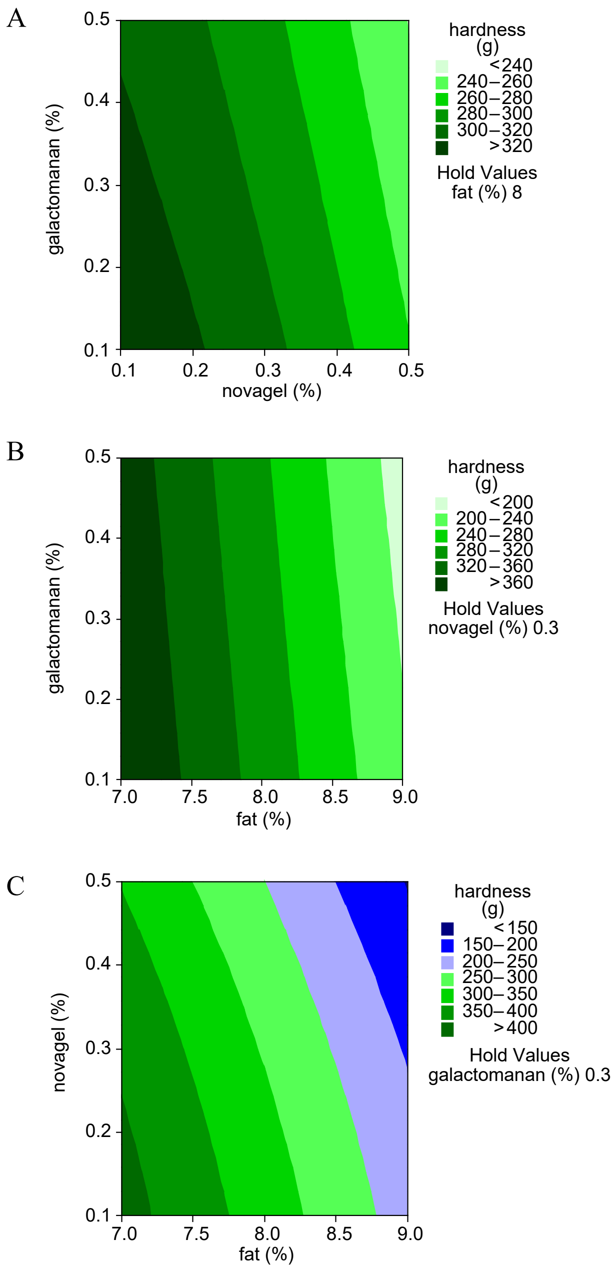

Fig. 1. Contour plot showing hardness of ultrafiltrated low-fat cheese: A – novagel × galactomannan, B – galactomannan × fat, C – novagel × fat

The investigation of the independent variables' interaction effects (the different concentrations of galactomannan, novagel, and fat) on the hardness variations in low-fat ultrafiltrated cheeses

Figure 1 illustrates the interaction effects of galactomannan × fat, galactomannan × novagel, and fat × novagel on the hardness of the low-fat ultrafiltered cheeses.

Figure 1A predicts the interaction effects of galactomannan and novagel concentrations on variations

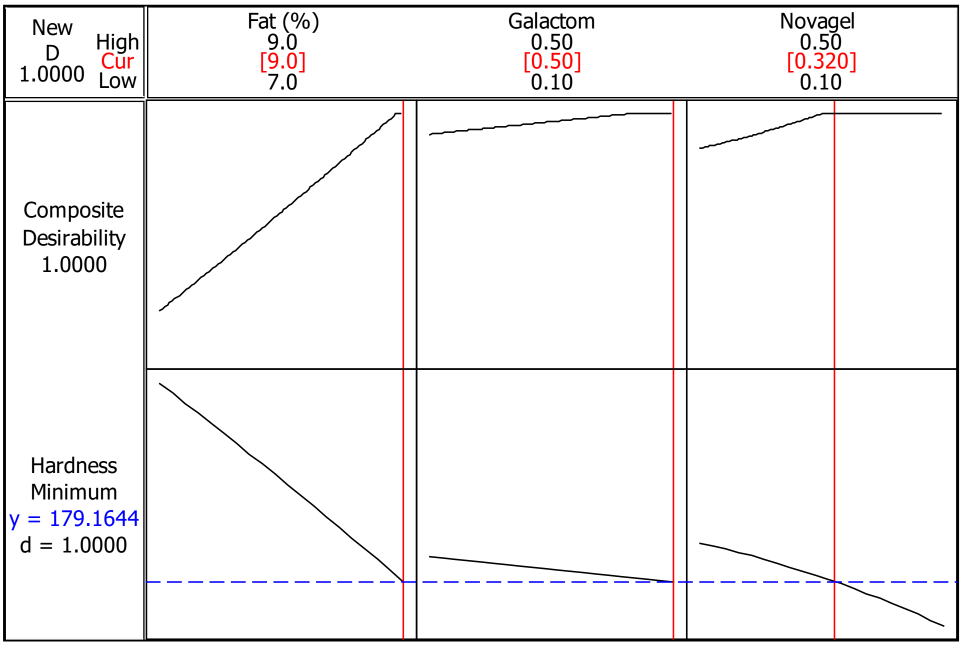

Fig. 2. Single optimization of ultrafiltrated low-fat cheese hardness

in cheese hardness when fat content is fixed in the central point (8%). With an increase in galactomannan and novagel concentrations in the cheeses, the hardness value decreased significantly. Based on the results, hardness values lower than 240 g were observed in the cheese containing 0.43 to 0.5% galactomannan and 0.11 to 0.5% novagel.

Figure 1B predicts the interaction effects of galactomannan concentration and fat percentage on variations in cheese hardness when the novagel value is fixed in the central point (0.3%). With an increase in the concentrations of galactomannan and fat, the cheese hardness value decreased significantly. Based on the results, hardness values lower than 200 g were observed in the cheese containing 0.28 to 0.5% galactomannan and 8.8 to 9% fat.

Figure 1C predicts the interaction effects of novagel concentration and the fat percentage on variations in cheese hardness when the galactomannan value is fixed in the central point (0.3%). With an increase in the concentrations of Novagel and fat, the cheese hardness value decreased significantly. Based on the results, hardness values between 150 to 200 g were observed in the cheese containing 0.28 to 0.5% Novagel and 8.6 to 9% fat.

Optimization of the hardness properties of ultrafiltrated low-fat cheese containing different concentrations of galactomannan and novagel

In order to produce a low-fat cheese with textural properties similar to full-fat cheese, an optimization technique was used in this study and the hardness value of the control high-fat cheese was considered as the objective. According to the results in Figure 2, the hardness value of the ultrafiltrated cheese containing 9% fat, 0.32% novagel, and 0.5% galactomannan was predicted about 179.1644 g with 100% desirability. The predicted formulation of low-fat cheese was produced in the lab. The result of the experimental hardness of cheese is 183.61 ±6.12. There is no significant difference between the predicted and the experimental cheese hardness.

RESULTS OF SENSORIAL EXPERIMENTS

Investigation of the effects of fat, novagel and galactomannan on the texture of low-fat ultrafiltrated cheese

The results in Table 5 show that by decreasing the fat content, the score of the texture decreased, while by

Table 5. Sensorial properties (scores) of low-fat ultrafiltrated cheese containing various concentrations of galactomannan and novagel and control sample

Sample codes	Galacto-mannan %	Novagel %	Cheese fat %	Texture	Color	Taste	Acceptability
B_1	0.3	0.3	8	4.350 ± 0.042^{ef}	4.770 ± 0.042^{a}	4.270 ± 0.042^{cd}	3.920 ± 0.042^{bcde}
A_2	0.3	0.1	7	3.410 ± 0.028^{h}	4.715 ± 0.049^{a}	3.550 ± 0.070^{i}	3.650 ± 0.495^{e}
B_5	0.5	0.1	8	4.064 ± 0.056^{bcd}	4.755 ± 0.049^{a}	4.350 ± 0.070^{abcd}	3.650 ± 0.070^{cde}
B_2	0.3	0.3	8	4.420 ± 0.028^{def}	4.755 ± 0.049^{a}	4.160 ± 0.056^{def}	4.070 ± 0.183^{abcde}
A_4	0.5	0.3	7	3.455 ± 0.063^{h}	4.675 ± 0.035^{a}	3.870 ± 0.042^{fgh}	3.450 ± 0.495^{de}
C_2	0.5	0.3	9	4.770 ± 0.042^{ab}	4.760 ± 0.042^{a}	4.600 ± 0.141^{ab}	4.550 ± 0.070^{abc}
A_1	0.3	0.5	7	3.450 ± 0.070^{h}	4.765 ± 0.049^{a}	3.960 ± 0.056^{efgh}	3.450 ± 0.049^{de}
C_1	0.3	0.1	9	4.515 ± 0.021^{cde}	4.765 ± 0.049^{a}	4.200 ± 0.141^{de}	4.775 ± 0.035^{ab}
B_4	0.1	0.1	8	4.480 ± 0.028^{cdef}	4.755 ± 0.063^{a}	3.850 ± 0.007^{ghi}	4.025 ± 0.1065^{abcde}
B_3	0.1	0.5	8	4.00 ± 0.141^{g}	4.745 ± 0.063^{a}	3.950 ± 0.070^{efgh}	3.695 ± 0.134^{cde}
B_7	0.3	0.3	8	4.320 ± 0.042^{ef}	4.740 ± 0.056^{a}	4.150 ± 0.070^{defg}	3.815 ± 0.120^{bcde}
C_3	0.1	0.3	9	4.470 ± 0.042^{cdef}	4.765 ± 0.049^{a}	4.150 ± 0.070^{defg}	4.050 ± 0.070^{abcde}
B_6	0.5	0.5	8	4.280 ± 0.028^{f}	4.770 ± 0.042^{a}	4.340 ± 0.056^{bcd}	4.415 ± 0.091^{abcd}
C_4	0.3	0.5	9	4.670 ± 0.042^{bc}	4.770 ± 0.028^{a}	4.550 ± 0.070^{abc}	4.460 ± 0.056^{abcd}
A_3	0.1	0.3	7	3.390 ± 0.028^{h}	4.765 ± 0.049^{a}	3.665 ± 0.049^{hi}	3.550 ± 0.4955^{cde}
D	0	0	23	4.950 ± 0.070^{a}	4.750 ± 0.070^{a}	4.650 ± 0.070^{a}	5.000 ± 0.000^{a}

The results are given as mean values ±SD
Different letters indicate a significant difference in columns.
D – control sample: prepared with 23% fat and no hydrocolloid.

increasing the galactomannan and novagel, the score of the texture increased. The lowest texture score (3.390) belonged to the A_3 treatment containing 7% fat, 0.1% galactomannan and 0.3% novagel, while the highest texture score (4.770) after the control sample (4.950) belonged to the C_2 treatment containing 9% fat, 0.5% galactomannan and 0.3% novagel, which didn't show a significant difference from control sample ($P \leq 0.05$).

Confirming the obtained results, Khedmati et al. (2013) investigated the effects of tragacanth gum on the texture of sheep's cheese. The results indicated that adding tragacanth gum to low-fat cheeses improves the textural and sensorial properties.

Rahimi et al. (2007) used tragacanth gum as a fat replacement for low-fat cheese, which reduced the hardness parameters of the texture, and improved some of the textural properties.

Volikakis et al. (2004), used different concentrations of beta-glucan extracted from oats as a fat substitute and reported that it could correct all texture indices of salt-water, low-fat cheese. However, beta-glucan had a negative effect on the appearance and taste of cheeses. In 2006, Lobato-Calleros et al. used various hydrocolloids, including pectin, carboxymethyl cellulose and arabic gum, as fat substitutes for low-fat cheese. The results showed that cheese containing carboxymethyl cellulose exhibits similar textural and rheological properties to full-fat white cheese.

Ghanbari Shanndi at al. (2011) studied the rheological, physicochemical and sensorial properties of Iranian low-fat white cheese. The results indicated an improvement in the texture of low-fat cheese by increasing the concentration of xanthan gum.

Cooke et al. (2013) studied the effects of tragacanth gum on the rheological and functional properties of full-fat and semi-fat cheddar cheese during storage. The results showed that tragacanth gum reduced the hardness and increased the softness of cheese during the production period, and improved the textural and functional properties of semi-fat cheese, while there was no sign of any adverse effects on the sensorial properties of the samples.

Drake et al. (1999) made use of lecithin of 0.2% and 0.5% for producing low-fat cheddar cheese and reported that lecithin improved the texture score in such a way that the score of low-fat cheeses containing the lecithin was higher than those without lecithin.

Sipahioglu et al. (1999) reported that adding lecithin to feta cheese caused a significant increment in the low-fat feta cheese's texture score.

Investigation of the effects of fat, novagel and galactomannan on the color of low-fat ultrafiltrated cheeses

Table 5 shows that the use of novagel and galactomannan had no significant effect on the color of the cheese samples ($p > 0.05$). The color scores of all low-fat cheeses were not significantly different from the control sample and are classified in a statistically identical group ($P > 0.05$). To confirm the results of this study, Kavas et al. (2004) reported that there is no statistically significant difference in the overall appearance score of low-fat cheese with a fat replacer compared to full-fat cheese.

Abd Karim at al. (1999) stated that adding kappa-carrageenan to the formulated tofu produced by calcium sulfate decreases the value of the b^* index and consequently yellowness in comparison with the control sample. However, this does not follow a particular order or system.

Romeih et al. (2002) reported that making use of simpless-D 100 increases the appearance score of low-fat cheese.

Investigation of the effects of fat, novagel and galactomannan on the taste of low-fat ultrafiltrated cheeses

The results in Table 5 show that changes in fat content and use of different densities of novagel and galactomannan had a significant effect ($p \leq 0.05$) on the taste scores of the produced cheeses. The results show that by reducing the amount of fat, the taste score decreases, but it can be improved by adding galactomannan and novagel.

The lowest taste rate (3.550) corresponded to treatment A_2 containing 7% fat, 0.3% galactomannan and 0.1% novagel, while the highest taste score after the control sample (4.650) belonged to treatment C_2 containing 9% fat and 0.5% galactomannan and 0.3% novagel, which had no significant difference compared with the control sample. The release of aromatic compounds from low-fat cheeses is influenced by the composition of the cheese. The molecular weight and hydrophobic nature of volatile compounds contribute to their ability to release value from the cheese structure (Lindenberg, 1951). Previous researchers have found that the esters molecular weight is of great importance in their ability to release value from the cheese texture (Taylor, 2002).

In addition to molecular weights, the hydrophobic content of volatile compounds is also of important for maintaining their levels in protein environments (Sostmann and Guichard, 1998). Since cheese is a protein matrix, keeping long chain esters in it is higher than short chain ones (Jouenne and Crouzet, 2000).

The reason for the difference in the taste of full-fat and low-fat cheeses is the difference in composition, the release of flavor and biochemical processes during production (Drake et al., 1999). Reducing the concentration of volatile compounds to affect the taste and odor resulting from the decomposition of fat along with bitterness is the main reason for the taste of cheeses, especially low-fat ones (Banks, 2004).

Milk fat has a major impact on the taste of cheese (Olson and Johnson, 1990), and lower-fat cheeses have a weaker taste mainly due to the higher moisture content and a lower share of fat in the cheese's overall taste (Sipahioglu et al., 1999). The results of Koca and Metins' research in 2007 state a higher taste rating in relation to a full-fat sample.

Aminifar et al. (2014) reviewed the effects of xanthan and condensed milk protein on the hardness of low-fat brined cheese and observed that, when xanthan is added to low-fat cheese, all of the esters released from the texture are decreased. This reduction in release is attributed to the bonding ability of the polysaccharides to aromatic compounds and trapping of the compounds in the gel network. Researchers have shown that the chemical properties of polysaccharides and the ability to form various bonds between them and aromatic compounds contribute to the release of these compounds, while resins such as xanthan and guar also have the ability to attach to flavor compounds (Jouenne and Crouzet, 2000; Naknean and Meenune, 2010).

Boland et al. (2006) reported that increasing the food hardness reduces their absorbing of flavor. It states that using xanthan reduces the hardness of low-fat cheese because of the ability of the polysaccharide to bind to esters and reduce the number which is released. It is worth mentioning that increasing the protein content of condensed milk in low-fat cheese will increase the hardness and the presence of beta-lactoglobulin, which has locations which bind to flavor compounds and reduces the release of esters (Aminifar et al., 2014).

Lower-fat cheeses tend to have less flavor than high-fat cheeses. This is due to the dilution of flavor in low-fat cheeses holding more moisture content (Baghdadi et al., 2017).

Madadlou et al. (2005) reported that Iranian low-fat white cheese has less flavor and texture scores than a full-fat one. Kavas et al. (2004) investigated the addition of hydrocolloid compounds based on whey proteins for producing low-fat cheese and reported that the mentioned compounds had no significant effect on the taste of the cheese. Sipahioglu et al. (1999) used lecithin in the production of full-fat cheese and reported that the mentioned combination reduced the cheese taste scores in comparison to the control sample.

The effects of fat, novagel and galactomannan on the acceptability of low-fat ultrafiltrated cheeses

The results in Table 5 show that changes in the fat content and the use of different concentrations of novagel and galactomannan had a significant effect ($P \leq 0.05$) on the acceptability of cheeses. The results also show that by decreasing the amount of fat, the acceptability score decreases while by adding galactomannan and novagel the acceptability of low-fat cheeses increases.

Considering these results, the lowest rate of acceptability (3.350) belonged to treatment A_2 containing 7% fat, 0.3% galactomannan and 0.1% novagel, and the highest score after the control sample belonged to treatment C_2 containing 9 % fat and 0.5% galactomannan and 0.3% novagel, which did not show any significant difference ($P > 0.05$) from the control sample.

These results confirm the investigation of Khedmati et al. (2013) which studied the effects of tragacanth gum on the textural and sensorial properties of sheep's cheese. This research investigated the effects of gum on four concentrations of 0.25, 0.5, 0.75 and 1 g of gum per kg of consumable milk. The results indicated that adding tragacanth gum in low concentrations improves the textural and sensorial properties.

Other research by Rashidi et al. (2015) stated that using guar, xanthan, lecithin and whey protein concentrate increases the acceptability of low-fat ultrafiltrated cheeses.

Zerfiridis et al. (2004) used beta-glucan concentrates as fat alternatives in low-fat cheese formulations. They reported that using the mentioned mixture has a negative effect on the appearance and taste of cheese.

Sipahioglu et al. (1999) investigated the functional properties of modified tapioca and lecithin starch in low-fat and reduced fat cheeses. The results indicated that reduced fat cheeses using tapioca starch have the highest amount of moisture, the least amount of protein, and the highest degree of hardness. The combination of tapioca and lecithin starch improves the taste, texture and overall acceptance of low-fat and reduced-fat cheeses.

Yahyavi and Mousavi Kolajahi (2014) used dietary fibers of inulin and dextrose as fat substitutes in feta cheese. Four treatments of feta cheese, i.e., without fat alternative, containing 1% poly-dextrose, 1% inulin and a mixture of 0.5% poly-dextrose and 0.5% inulin were produced. The results of the sensorial evaluation showed that the combination of poly-dextrose and inulin leads to an improvement in taste, texture and overall acceptability in low-fat cheese.

CONCLUSION

The main goals of this research are the optimization of the textural properties, the study of the possibility of producing low-fat cheese (with 7–9% fat) containing various concentrations of galactomannan and novagel (0.1–0.5%), an evaluation of the physicochemical, textural and sensorial properties of low-fat cheeses, and a comparison of them with full-fat cheese. The results showed that decreasing the fat in cheese used to make milk and adding different hydrocolloids as fat alternatives (such as novagel and galactomannan) increases the amount of ash, moisture, acidity, salt and protein. Using different concentrations of fat, novagel and galactomannan did not have significant effects on the dry matter of cheese treatments ($P > 0.05$). The effects of fat, galactomannan and novagel on the textural and sensorial changes in low-fat cheeses were significant ($P \leq 0.05$). Reducing the amount of fat in low-fat cheeses increases their hardness. A major part of the undesirable changes in the textural and sensorial properties of fat reduced cheese was improved by the addition of novagel and galactomannan. The results showed that the textural and sensorial properties of the treatment containing 9% fat and 0.5% galactomannan and 0.3% novagel were not significantly different from the control sample.

Simultaneous optimization of the properties of low-fat ultrafiltrated cheeses via the response-surface method showed that low-fat cheese containing 9% fat, 0.32% novagel, and 0.5% galactomannan creates the maximally desirable textural properties similar to those of full-fat cheeses. The results of this research also showed that by using galactomannan and novagel in the formulation of low-fat cheese can lead to the production of low-fat cheese with favorable textural and sensorial properties close to those of full-fat cheese.

REFERENCES

Abd Karim, A., Sulebele, G., Azhar, M., Ping, C. (1999). Effect of carrageenan on yield and properties of tofu. Food Chem., 66(2), 159–165. https://doi.org/10.1016/S0308-8146(98)00258-1

Akbari, A., Ghorbani, M., Sadeghi Mahonk, A., Alaami, M., Kashani Nejad, M. (2015). Effect of seed gum size and isolation of soybean protein on the stabilization of oil-in-water emulsion. Quart. J. New Food Technol., 3(10), 23–32.

Aminifar, M., Emam-Djome, Z., Belgheisi, S. (2014). Effect of xanthan and milk protein concentrate on hardness, microstructure and ester release of low-fat brined cheese. Iran. J. Nutr. Sci. Food Technol., 9(1), 83–92. http://nsft.sbmu.ac.ir/article-1-1602-en.html

AOAC (1995a). AOAC official methods of analysis. Washington, MD: Association of Official Analytical Chemists.

AOAC (1995b). AOAC official methods of analysis (16th ed.). Arlington, MD: Association of Official Analytical Chemists.

AOAC (2005). Official methods of analysis of AOAC International. Vol. II. Methods of analysis (18th ed.). Gaithersburg, MD, USA: Association of Official Analytical Chemists.

Azarnia, S., Ehsani, M. R., Mirhanli, S. A. (1997). Evaluation of the physico-chemical characteristics of the curd during the Ripening of Iranian brine cheese. Int. Dairy J., 7(7), 473–478. https://doi.org/10.1016/S0958-6946(97)00034-4

Banks, J. M. (2004). The technology of low-fat cheese manufacture. Int. J. Dairy Technol., 57(4), 199–220. https://doi.org/10.1111/j.1471-0307.2004.00136.x

Baghdadi, F., Aminifar, M., Farhoudi, M., Shojaee Aliabadi, S. (2017). Investigating relationship between FTIR spectrometry and characteristics of low-fat Iranian white cheese improved by tragacanth gum *Astragalus Parrowianus*. J. Nutr. Nutr. Sci. Iran., 12(3), 109–120.

Bench, A. (2007). Water binders for better body: Improving texture and stability with natural hydrocolloids. Food Bev. Asia, 32–33.

Boland, A. B., Delahunty, C. M., van Ruth, S. M. (2006). Influence of the texture of gelatin gels and pectin gels onstrawberry flavour release and perception. Food Chem., 96(3), 452–460.

Bryant, A., Ustunol, Z., Steffe, J. (1995). Texture of Cheddar cheese as influenced by fat reduction. J. Food Sci., 60(6), 1216–1219.

Bylund, G. (1995). Dairy processing handbook (pp. 331–352). Lund: Tetra Pak Processing Systems AB.

Braga, A., Azevedo, A., Marques, M., Menossi, M., Cunha, R. (2006). Interactions between soy protein isolate and Xanthan in heat-induced gels: the effect of salt addition. Food Hydrocoll., 20(8), 1178–1189. https://doi.org/10.1016/j.foodchem.2005.02.027

Cardarelli, H. R., Buriti, F. C. A., Castro, I. A., Saad, S. M. I. (2008). Inulin and oligofructose improve sensory quality and increase the probiotic viable count in potentially synbiotic petit-puisse cheese. LWT – Food Sci. Technol., 41(6), 1037–1046. http://dx.doi.org/10.1016/j.lwt.2007.07.001

Cooke, D. R., Khosrowshahi, A., McSweeney, P. L. (2013). Effect of tragacanth gum on the rheological and functional properties of full-fat and half-fat Cheddar cheese. Dairy Sci. Technol., 93(1), 45–62.

Danesh, A., Joiandeh, H., Goodarzi, M. (2016). Effect of transglutaminase treatment on physicochemical, rheological and organoleptic characteristics of low-fat supplemented cheese combined with water cheese proteins during storage. J. Food Nutr. Res., 14(4), 25–36.

Dickinson, E. (1998). Stability and rheological implication of electrostatic milk protein-polysaccharide interactions. Trends Food Sci. Technol., 9(10), 347–354. http://10.1016/S0924-2244(98)00057-0

Drake, M. A., Truong, V. D., Daubert, C. R. (1999). Rheological and sensory properties of reduced-fat processed cheeses containing lecithin. J. Food Sci., 64(4), 744–747. https://doi.org/10.1111/j.1365-2621.1999.tb15123.x

Esperan, V., Ghanbarzadeh, B., Hosseini, S. A. (2011). The effect of hydrocolloid carrageenan and glucono-delta lactone and calcium chloride on rheological, physical and sensorial properties of soy cheese (tofu). Iran. J. Nutr. Sci. Food Technol., 6(1), 81–90.

Fadaei, V., Poursharif, K., Daneshi, M., Honarvar, M. (2012). Chemical characteristics of low-fat whey less cream cheese containing inulin as fat replacer. Eur. J. Exp. Biol., 2(3), 690–694.

Fenelon, M. A., O'Connor, P., Guinee, T. P. (2000). The effect of fat content on the microbiology and proteolysis in cheddar cheese during ripening. J. Dairy Sci., 83(10), 2173–2183. https://doi.org/10.3168/jds.S0022-0302(00)75100-9

Fox, P. F., Guinee, T. P., Cogan, M. T., McSweeney, P. L. H. (2000). Fundamentals of cheese science (pp. 157–174). Philadelphia, United States: Aspen Publishers.

Fox, P. F., McSweeney, P. L., Cogan, T. M., Guinee, T. P. (2004). Cheese: Chemistry, physics and microbiology. Vol. 1. General aspects. Academic Press.

Ghanbari Shandi, A., Khosroshahi Asl, A., Mortazavi, A., Tavakoli Pour, H. (2011). Effect of Xanthan gum on the histological and rheological properties of Iranian low-fat white cheese. J. Food Sci. Technol., 8(1), 35–46.

Goudarzi, M., Madadlou, A., Mousavi, M. E., Emam--Djomeh, Z. (2015). Formulation of apple juice beverages containing whey protein isolate or whey protein hydrolysate based on sensory and physicochemical analysis. Int. J. Dairy Technol., 68(1), 70–78. https://doi.org/10.1111/1471-0307.12155

Gunasekaran, S., Mehmet, A. K. M. (2003). Cheese rheology and texture (pp. 281–284). Boca Raton: CRC Press. https://doi.org/10.1201/9781420031942

Hayaloglu, A. A., Guven, M., Fox, P. F. (2002). Microbiological, biochemical and technological properties of Turkish white cheese 'Beyaz Peynir'. Int. Dairy J., 12(8), 635–648. https://doi.org/10.1016/s0958-6946(02)00055-9

Hosseini, M., Habibi Najafi, M. B., Mohebbi M. (2011). Physicochemical properties of imitation cheeses containing guar gum and aromatic Lighvan cheese. In Proceedings of the First National Conference of Food Industry, February 28–29. Quchan, Iran.

Jouenne, E., Crouzet, J. (2000). Effect of pH on retention of aroma compounds by beta-lactoglobulin. J. Agric. Food Chem., 48(4), 1273–1277. https://doi.org/10.1021/jf990215w

Katsiari, M. C., Voutsinas, L. P., Kondyli, E., Alichanidis, E. (2002). Flavour enhancement of low-fat Feta-type cheese using a commercial adjunct culture. Food Chem., 79, 193–198. http://dx.doi.org/10.1016/S0308-8146(02)00131-0

Kavas, G., Oysun, G., Kinik, O., Uysal, H. (2004). Effect of some fat replacers on chemical, physical and sensory attributes of low-fat white pickled chees. Food Chem. J., 88(3), 381–388. https://doi.org/10.1016/j.foodchem.2004.01.054

Khedmati, Sh., Mohammadzadeh Milani, J., Ghorbani Hassan Sarabi, A. (2013). Investigating the effect of tragacanth gum on the sheep's cheese texture. In Proceedings of the 21rd National Congress of Science and Technology, October 29–31. Shiraz, Iran.

Koca, N., Metin, M. (2004). Textural, melting and sensory properties of low-fat fresh Kashar cheeses produced by using fat replacers. Int. Dairy J., 14(4), 365–373. https://doi.org/10.1016/j.idairyj.2003.08.006

Kurultay, S., Oksuz, O., Simsek, O. (2000). The effect of hydrocolloids on some physicochemical and sensory properties and on the yield of Kashar cheese. J. Cent. Eur. Agric., 44(5), 377–378. https://doi.org/10.1002/1521-3803(20001001)44:5<377::AID-FOOD377>3.0.CO;2-L

Madadlou, A., Khosroshahi, A., Mosavi, M. E. (2005). Rheology, macrostructure and functionality of low-fat Iranian White cheese made with different concentration of rennet. J. Dairy Sci., 88, 3052–3062. https://doi.org/10.3168/jds.S0022-0302(05)72986-6

Madadlou, A., Khosroshahi, A., Mosavi, M. E. (2007a). Rheology, microstructure and functionality of low-fat

Iranian White cheese made with different concentration of rennet. J. Dairy Sci., 88(9), 3052–3062.

Madadlou, A., Mosavi, M. E., Khosrowshahi, A., Emamjome, Z., Zargaran, M. (2007b). Effect of cream homogenization on textural characteristics of low-fat Iranian White cheese. Int. Dairy J., 17, 547–554. https://doi.org/10.1016/j.idairyj.2006.07.006

McMahon, D. J., Alleyne, M. C., Fife, R. L., Oberg, C. J. (1996). Use of fat replacers in low-fat Mozzarella cheese. J. Dairy Sci., 79(11), 1911–1921. https://doi.org/10.3168/jds.S0022-0302(96)76560-8

Mistry, V. V. (2001). Low fat cheese technology. Int. Dairy J., 11, 413–422. https://doi.org/10.1016/S0958-6946(01)00077-2

Mistry, V. V., Metzger, L. E., Maubios, J. L. (1996). Use of ultrafiltered sweet buttermilk in the manufacture of reduced fat Cheddar cheese. J. Dairy Sci., 79(7), 1137–1145. https://doi.org/10.3168/jds.S0022-0302(96)76467-6

Lashgari, H., Khosrowshahi Asl, A., Golkari, H., Ashrafiyurqanlou, R., Zohri, M. (2008). Investigating the possibility of producing Iranian white cheese with low-fat content and optimizing its characteristics using Arabic and Guar gum. J. Nutr. Sci. Food Technol. Iran., 3(3), 1–10. http://doi.10.1007/s13197-012-0768-y

Lindenberg, B. A. (1951). Sur la solubilité des substances organiques amphipatiques dans les glycérides neutres et hydroxyles. J. Chem. Phys., 48, 350–355. https://doi.org/10.1051/jcp/1951480350

Lobato-Calleros, C., Robles-Martinez, J. C., Caballero--Perez, J. F., Aguirre-Mandujano, E. (2001). Fat replacers in low-fat Mexican Manchego cheese. J. Texture Stud., 32(1), 1–14. https://doi.org/10.1111/j.1745-4603.2001.tb01030.x

Lobato-Calleros, C., Rodriguez, E., Sandoval-Castilla, O., Vernon-Carter, E., Alvarez-Ramirez, J. (2006). Reduced-fat white fresh cheese-like products obtained from $W_1/O/W_2$ multiple emulsions: Viscoelastic and high-resolution image analyses. Res Int., 39(6), 678–685. https://doi.org/10.1016/j.foodres.2006.01.006

Mohammadzadeh Milani, J., Khedmati, Sh., Ghorbani Hassan Sarai, A., Golkar, A. (2017). The effect of tragacanth gum on physicochemical and textural properties of Lighvan cheese during the production period. J. Res. Innov. Food Sci. Technol., 6(1), 103–114.

Naknean, P., Meenune, M. (2010). Factors affecting retention and release of flavor compounds in food carbohydrates. Int. Food Res. J., 17(1), 23–34.

Nateghi, L., Roohinejad, S. H., Totosaus, A., Rahmani, A., Tajabadi, N., Meimandipour, A., ..., Manap, M. Y. A. (2012). Physicochemical and textural properties of reduced fat Cheddar cheese formulated with xanthan gum and/or sodium caseinate as fat replacers. J. Food Agric. Environ., 10(2), 59–63.

Nebizadeh, F., Khosroshahi Asl, A., Zomorodi, Sh., Esmaeili, M. (2016). Effect of tragacanth gum and Exopolysaccharide producer on quality, texture and microstructural characteristics of cheddar cheese. J. Food Ind. Res., 26(3), 357–367.

Olson, N. F., Johnson, M. E. (1990). Low-fat cheese technology. Int. J. Food Eng., 22, 31–37.

Połtorak, A., Wyrwisz, J., Moczkowska, M., Marcinkowska-Lesiak, M., Stelmasiak, A., Ulanicka, U., ..., Sun, D. W. (2015). Correlation between instrumental texture and colour quality attributes with sensory analysis of selected cheeses as affected by fat contents. Int. J. Food Sci. Tech., 50(4), 999–100. https://doi.org/10.1111/ijfs.12707

Rahimi, J., Khosrowshahi, A., Madadlou, A., Aziznia, S. (2007). Texture of low-fat Iranian White cheese as Influenced by Gum tragacanth as fat replacer. J. Dairy Sci., 90(9), 4058–4070. https://doi.org/10.3168/jds.2007-0121

Rashidi, H., Mazaheri-Tehrani, M., Razavi, S. M. A., Ghods-Rohany, M. (2015). Improving textural and sensory characteristics of low-fat UF Feta cheese made with fat replacers. J. Agric. Sci. Technol., 17(1), 121–132.

Rolle, L., Giordano, M., Giacosa, S., Vincenzi, S., Segadea, S. R., Torchio, F., Perrone, B., Gerbi, V. (2012). CIE L*a*b* parameters of white dehydrated grapes as quality markers according to chemical composition, volatile profile and mechanicalproperties. Anal. Chim. Acta, 732, 105–113.

Romeih, E. A., Michaelidou, A., Biliaderis, C. G., Zerfiridis, G. K. (2002). Low-fat white-brined cheese made from bovine milk and two commercial fat mimetics: chemical, physical and sensory attributes. Int. Dairy J., 12(6), 525–540. https://doi.org/10.1016/S0958-6946(02)00043-2

Rudan, M. A., Barbano, D. M., Yun, J. J., Kindstedt, P. S. (1999). Effect of fat content reduction on chemical composition, proteolysis, functionality, and yield of Mozzarella. J. Dairy Sci., 82(4), 661–672. https://doi.org/10.3168/jds.S0022-0302(99)75282-3

Rustamabadi, H., Joyandeh, H., Hojjati, M. (2017). Optimization of physicochemical, sensorial, and color characteristics of Iranian ultrafiltration white cheese of low fat content, containing fat substitutes using the response surface method. J. Food Sci. Technol., 14(63), 91–106.

Volikakis, P., Biliaderis, C. G., Vamvakas, C., Zerfiridis, G. K. (2004). Effects of a commercial oat-ß-glucan concentration on the chemical, physico-chemical and sensory attributes of a low-fat white-brined cheese product. Food Res. Int., 37(1), 83–94. https://doi.org/10.1016/j.foodres.2003.07.007

Yahyavi, F., Mousavi Koljahi, A. (2014). The study of the possibility of production of Feta low-fat cheese using dietary fiber. In Proceedings of the National Conference on Recent Achievements in Engineering Sciences and Technology, July 31. Mamaghan, Iran.

Zalazara, C. A., Zalazara, C. S., Bernala, S., Bertolab, N., Bevilacquab, A., Zaritzky, N. (2002). Effect of moisture level and fat replacer on physicochemical rheological and sensory properties of low-fat soft cheeses. Int. Dairy J., 12(1), 45–50.

Zerfiridis, G. K., Biliaderis, C. G., Volikakis, P., Vamvakas, C. (2004). Effects of a commercial oat-β-glucan concentrate on the chemical, physical-chemical and sensory attributes of a low-fat white-brined cheese product. Int. Dairy J., 37(1), 83–94.

Zhang, L. B., Lv, J. L., Chen, H. L. (2013). Japonicasins A and B, two new isoprenylated flavanones from *Sophora japonica*. Fitoterapia, 87, 89–92. https://doi.org/10.1016/j.fitote.2013.03.019