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Optimization and evaluation of textural properties of ultra-filtrated low-fat cheese containing galactomannan and Novagel gum

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Abstract

The general aim of this research was to optimise textural properties and to evaluate the possibility of producing ultra-filtrated low-fat cheese (7-9 % (w/w)), containing various concentrations of galactomannan and Novagel (0.1-0.5 % w/w), and assessing textural properties of produced low-fat cheeses and comparing them with full fat ones. According to the results, reducing fat implies increasing the hardness, cohesiveness, gumminess and chewiness of the tested samples. On the other hand, adding galactomannan gum and Novagel, and increasing their concentration, implies reducing all of the above mentioned textural properties. According to the results, increasing the amount of fat and using galactomannan and Novagel gum, implies increasing the adhesiveness and springiness of the tested treatments. The results showed that textural properties including hardness, adhesiveness, cohesiveness, gumminess and chewiness, of sample containing 9 % (w/w) fat, 0.5 % (w/w) galactomannan, and 0.3 % (w/w) Novagel were not of significantly different from the control sample and was selected as the superior sample. Multiple optimization of the low-fat cheeses textural properties via Response Surface Method (RSM) software showed that the treatment containing 9 % (w/w) fat, 0.1 % (w/w) Novagel and 0.46% (w/w) galactomannan fulfils 84 % of desirable properties of a full fat cheese.

Key words: **galactomannan, hydrocolloid, Novagel, ultra-filtrated, low-fat cheese**

Introduction

Dairy products are of high nutritional value thus showing a constant increase in production and consumption (Fadaei et al., 2012). Cheese is one of the most widely used food products. Consumers expect low-fat and reduced-fat cheeses to have the same characteristics as full-fat cheese, and wish to increase their consumption if there is low-fat and flavoured cheese (Nateghi et al., 2012). On the other hand, excessive intake of fat causes diseases such as extreme obesity or cardiovascular disease, and a variety of cancers, leading consumers to pay attention to fat harmfulness (Arzani et al., 2014).

The amount of fat plays an important role in the functional, textural cheese characteristics (Nateghi et al., 2012).

Reducing fat causes defects such as loss of flavour, structure (proper structure), weak texture, and ultimately decreasing its acceptability (Sadowska et al., 2009). These problems result from the low moisture level in non-fat solids, proteolysis activity, free fat, high levels of protein, and salt in low fat cheese comparing with full-fat one (Nateghi et al., 2012; Sadowska et al., 2009). Fat alternatives are macromolecules of similar physical and chemical properties to triglycerides (ordinary oils and fats) in terms of replacing the fat in foods by one to one or gram by gram ratios. Carbohydrate-based fat substitutes are a good alternative for fat in food formulations due to textural and organoleptic properties. Carbohydrates typically play a role as fat, absorbing the water and playing a role of plasticizer thus creating a mouthfeel similar to fat. Galactomannans are natural polysaccharides derived from endosperm seeds of some legumes, which are widely used as gum in the food industry and in other industries (Zhang and Chen, 2013). Highly hydrophilic gum with high molecular weight and a set of polysaccharides and some proteins able to dissolve or swell in water, increase viscosity. Today, these compounds are widely used in various industries for condensation, gelling, film formation, foam stabilization, emulsion and dispersion, preventing the formation of ice and sugar crystals, as well as controlled releasing of flavours. (Akbari et al., 2015). Novagel is a mixture of fine cellulose crystals (MCC) and Guar gum derived from fruits and vegetables used as fat replacement in food processes (McMahon et al., 1996).

Kaveh and Ghowchani, (2014) studied the effect of applying various hydrocolloids (inulin and a mixture of Arabic gum and Guar gum) as fat alternative in the production of low-fat cheese. The results showed that making use of inulin and the ratio of Arabic and Guar gums in the combination of these two hydrocolloids have different and acceptable effects on rheological properties, fat content, dry matter content, free fatty acids, salt content, acidity and the total amount of bacteria in the cheese made in the process of production of low-fat one. Generally, we conclude using some of the hydrocolloids, such as Guar gum, low-fat cheese disadvantages are removed. Lobato-Calleros et al. (2006) produced low fat cheese containing various hydrocolloids including pectin, carboxymethyl cellulose, and Arabic gum. The results showed that low fat cheese containing carboxymethyl cellulose showed similar textural and rheological properties to full fat control cheese.

Salari et al. (2017) studied the effect of xanthan gum and carboxymethyl cellulose on the chemical and sensorial properties of cream cheese. The results showed no significant differences in the pH value of the sample, and increasing xanthan and carboxymethyl cellulose leads reducing cream cheese content of dry matter. Sensorial properties including texture, flavour, smell, colour and overall acceptance showed that the replacement of xanthan and carboxymethyl cellulose affected the overall acceptance of the product.

The aim of this research was optimization and evaluation textural properties of ultra-filtrated low-fat cheese containing Galactomannan and Novagel gum and comparing it with full-fat one as a control sample.

Materials and methods

To prepare cheese, Skim milk ultrafiltrated concentrate, Milk protein concentrate, Skim milk powder and Animal butter were purchased from Pegah (Tehran, Iran). Novagel 110 was purchased from Food Chem (Shanghai, China) and Galactomannan Gum was purchased 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, U.S.A) and salt was purchased from Golha (Tehran, Iran).

Preparation of ultra filtrated cheese

In the current research, skim milk ultrafiltrated concentrate 70 % (w/w), milk protein concentrate 12 % (w/w) and skim milk powder 4% (w/w) were mixed well by water (the amount of consumed water was calculated from the sum of the compounds used in the ultrafiltrated formulation minus 100) in pasteurizer at a temperature of 50 °C in order to make ultrafiltrated cheese. Then to adjust the final fat level in the ultrafiltrated cheese (7 % (w/w), 8 % (w/w), 9 % (w/w), and 22 % (w/w)), animal butter (82 % (w/w)) were mixed at a temperature of 60 °C until the butter was fully melted. After that, different concentrations of Novagel gum and Galactomannan were weighted and added to the mixture based on the treatments (Table 1). The mixture was well stirred and homogenized at a temperature of 75 °C and a pressure of 90 bar using Ultra-Turrax homogenizer (IKA10, Germany T-Basic) and then, it was pasteurized at 78 °C for 5 minutes in pasteurizer (VB-1820J, Faraz Electronic, Iran). After pasteurization, the temperature of milk was reduced to 34 °C following the addition of 0.03 % (w/w) direct-to-vat frozen mesophilic lactic starter cultures (R-704: *Lactacoccus lactis* spp. *cremories* and *Lactococcus lactis* spp. *lactis*) and 0.05 % (w/w) rennet enzyme. Subsequently, the mixture was stirred well and filled in 100 g containers. After the curds were formed, 2 % (w/w) of the salt was splashed on them. Then thermal sealing was done using polypropylene laminated Al-foil; the samples were incubated at 33 °C for 24 h and then transferred into a refrigerator set to 5 °C (Rashidi et al., 2011).

Textural profile analysis (TPA)

The textural profile of the cheeses was tested by a texture analyser (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 cut of the same dimensions is placed into the device and pressed twice by a pressing probe. Imitating the human textural perception, the first and second pressures simulating the first and second stages of human biting are. This method, enables the investigation of the indexes of hardness, cohesiveness, adhesiveness, springiness, gumminess and chewiness (Rolle et al., 2012). To conduct the tests, a 3.6 mm diameter cylindrical probe with progressive forehead at a temperature of 6 °C when cutting and ambient temperature (25 °C) during testing and a sample size of 1 cm × 1 cm, with a pre-test of 30 mm/min are used.

Design of treatments and data analysis method

To design the treatments, three independent variables determining the fat content of low-fat cheeses (9-7 % (w/w)) and different concentrations of Galactomannan and Novagel (0.1-0.5 % (w/w)) according to the method of RSM Box Behnken (Table 1) were used. Therefore, 15 treatments were designed and the results of the tests are compared with high-fat cheese. The results of textural properties of low-fat cheese samples produced were analysed by One Way Anova Tukey method and compared with the control sample. To achieve the best formulation of low-fat cheeses having textural characteristics similar to the control sample, single and multiple optimization was carried out by the RSM Box Behnken software. Then, the results of textural properties of full-fat cheese samples were selected as the target. All results are analysed in Minitab software 16.

TABLE 1. Different levels of independent variables including cheese fat content, various concentrations of Galactomannan and Novagel

Independent variable % (w/w)	Treatment	Content		
		-1	0	+1
Fat	(x_1)	7	8	9
Novagel	(x_2)	0.1	0.3	0.5
Galactomannan	(x_3)	0.1	0.3	0.5

Results and discussion

Results of textural properties ultrafiltrated low-fat cheeses

Table 2 presents result of textural properties of low-fat cheeses containing different concentrations of Galactomannan and Novagel in comparison to full-fat control cheese. Table 3 and in Figure 1 give the results of analysis of the variance of textural properties and the individual optimization of textural properties of low fat cheeses, while in Figure 2 multiple optimization of all textural properties is shown.

TABLE 2. Textural properties of low-fat ultra-filtering cheese containing different concentrations of Galactomannan, Novagel and control sample

Treatment Code	Galacto-mannan % (w/w)	Novagel % (w/w)	Cheese Fat % (w/w)	Hardness (g)	Adhesiveness (g.s)	Springiness	Cohesiveness	Gumminess	Chewiness
B1	0.3	0.3	8	323±4^{g}	-21.68±0.092^{d}	0.25±0.001^{ef}	0.43±0.004^{de}	140±3.12^{f}	35.5±0.9^{bc}
A2	0.3	0.1	7	451±1^{a}	-23.85±0.078^{e}	0.19±0.001^{h}	0.54±0.007^{a}	246±2.632^{a}	47.3±0.8^{a}
B5	0.5	0.1	8	347±2^{ef}	-21.95±0.148^{d}	0.26±0.003^{e}	0.43±0.006^{de}	151±3.41^{ef}	39.5±0.3^{b}
B2	0.3	0.3	8	325±3^{fg}	-21.65±0.071^{d}	0.25 ±0.006^{e}	0.43±0.005^{de}	141± 3.16^{f}	36.1±1.7^{bc}
A4	0.5	0.3	7	403±3^{bc}	-23.25±0.106^{e}	0.21±0.002^{g}	0.46±0.006^{b}	188±0.72^{bc}	40.1±0.5^{b}
C2	0.5	0.3	9	217±12^{k}	-16.82±0.530^{a}	0.33±0.004^{b}	0.37±0.002^{f}	80±5.72^{i}	27.1±1.5^{e}
A1	0.3	0.5	7	383±4^{cd}	-23.23±0.064^{e}	0.21±0. 003^{g}	0.46±0.004^{bc}	1785±0.40^{cd}	38.5±0.7^{b}
C1	0.3	0.1	9	249±1^{ij}	-20. 42±0.297^{bc}	0.31±0.001^{c}	0.39±0.002^{f}	97±1.47^{h}	30.6±0. 3de
B4	0.1	0.1	8	364±1de	-21.92±0.170^{d}	0.23±0.003^{g}	0.45±0.004^{bcd}	166±2.38^{de}	39.4±1.1^{b}
B3	0.1	0.5	8	287±3^{h}	-21.56± 0.085^{d}	0.26±0.006^{e}	0.43±0.004^{de}	124±2.96^{g}	33.0±1.5^{cd}
B7	0.3	0.3	8	323±3^{g}	-21.69±0. 057^{d}	0.25±0.004^{ef}	0.43±0.002^{cde}	141±2.35^{f}	35.9±1.2^{bc}
C3	0.1	0.3	9	243±0.5^{j}	-20.24±0.191^{b}	0.31±0.049^{c}	0.38±0.007^{f}	93±0.05^{hi}	29.1±0.4^{de}
B6	0.5	0.5	8	267±4^{hi}	-21.32±0.184^{cd}	0.28± 0.005^{d}	0.42± 0.002^{e}	122 ±2.32^{g}	32.0±1.2^{cd}
C4	0.3	0.5	9	171±0.7^{l}	-16.63±0.403^{a}	0.33±0.007^{b}	0.37±0.003^{f}	63±0.89^{j}	21.2±0.1^{f}
A3	0.1	0.3	7	421±1^{b}	-23.85±0.049^{e}	0.19±0.000^{gh}	0.47±0.024^{b}	199±9.27^{b}	39.6±1.6^{b}
D	0	0	23	209±1^{k}	-16.91±0.410^{a}	0.38±0.004^{a}	0.37± 0.002^{f}	78±5.50^{i}	30.6±1.7^{de}

Different letters indicate a significant difference in each column. Control: Prepared with 23 % (w/w) fat and no hydrocolloids. The results are given as mean values±SD.

TABLE 3. Analysis of variance textural properties of ultrafiltrated low-fat cheeses

Source	Hardness (g)		Adhesiveness (g.s)		Springiness		Cohesiveness		Gumminess		Chewiness	
	F	P	F	P	F	P	F	P	F	P	F	P
Regression	142.55	0.000*	10.46	0.000*	825.97	0.000*	14.91	0.004*	50.20	0.000*	18.76	0.002*
Linear	426.40	0.000*	28.33	0.001*	2456.07	0.000*	42.12	0.001*	148.72	0.000*	54.89	0.000*
Fat (x_1)	1099.25	0.000*	76.04	0.000*	6906.30	0.000*	114.09	0.000*	386.21	0.000*	125.40	0.000*
Novagel (x_2)	167.87	0.000*	5.52	0.066	277.98	0.000*	11.05	0.021*	55.93	0.001*	39.07	0.002*
Galactomannan (x_3)	12.07	0.018*	3.43	0.123	183.95	0.000*	1.21	0.321	4.01	0.102	0.21	0.669
Square	1.05	0.447	0.79	0.551	20.13	0.003	1.22	0.393	0.60	0.640	1.17	0.409
Fat× Fat (x_1^2)	0.38	0.564	2.33	0.188	39.43	0.002*	0.12	0.747	0.65	0.458	3.30	0.129
Novagel × Novagel (x_2^2)	2. 87	0.151	0.00	0.989	12.82	0.016*	1.74	0.244	0.15	0.717	0.10	0.764
Galactomannan ×Galactomannan (x_3^2)	0.00	0.972	0.00	0.987	16.40	0.010*	1.53	0.271	0.89	0.390	0.02	0.887
Interaction	0. 20	0.894	2.26	0.200	1.70	0.282	1.39	0.347	1.26	0.381	0.21	0.887
Fat× Novagel ($x_1 \times x_2$)	0.35	0.578	3.79	0.109	0.54	0.496	4.09	0.099	3.77	0.110	0.03	0.860
Fat× Galactomannan ($x_1 \times x_3$)	019	0.677	2.95	0.147	3. 82	0.108	0.04	0.857	0.01	0.934	0.49	0.514
Novagel × Galactomannan ($x_2 \times x_3$)	0.04	0.874	0.03	0.872	0.73	0.432	0.05	0.831	0.02	0.906	0.10	0.768
Lack-of-Fit	86.52	0.11	2316.91	0.000	3.32	0.0240	0.009	115.57	344.67	0.003	61.53	0.016

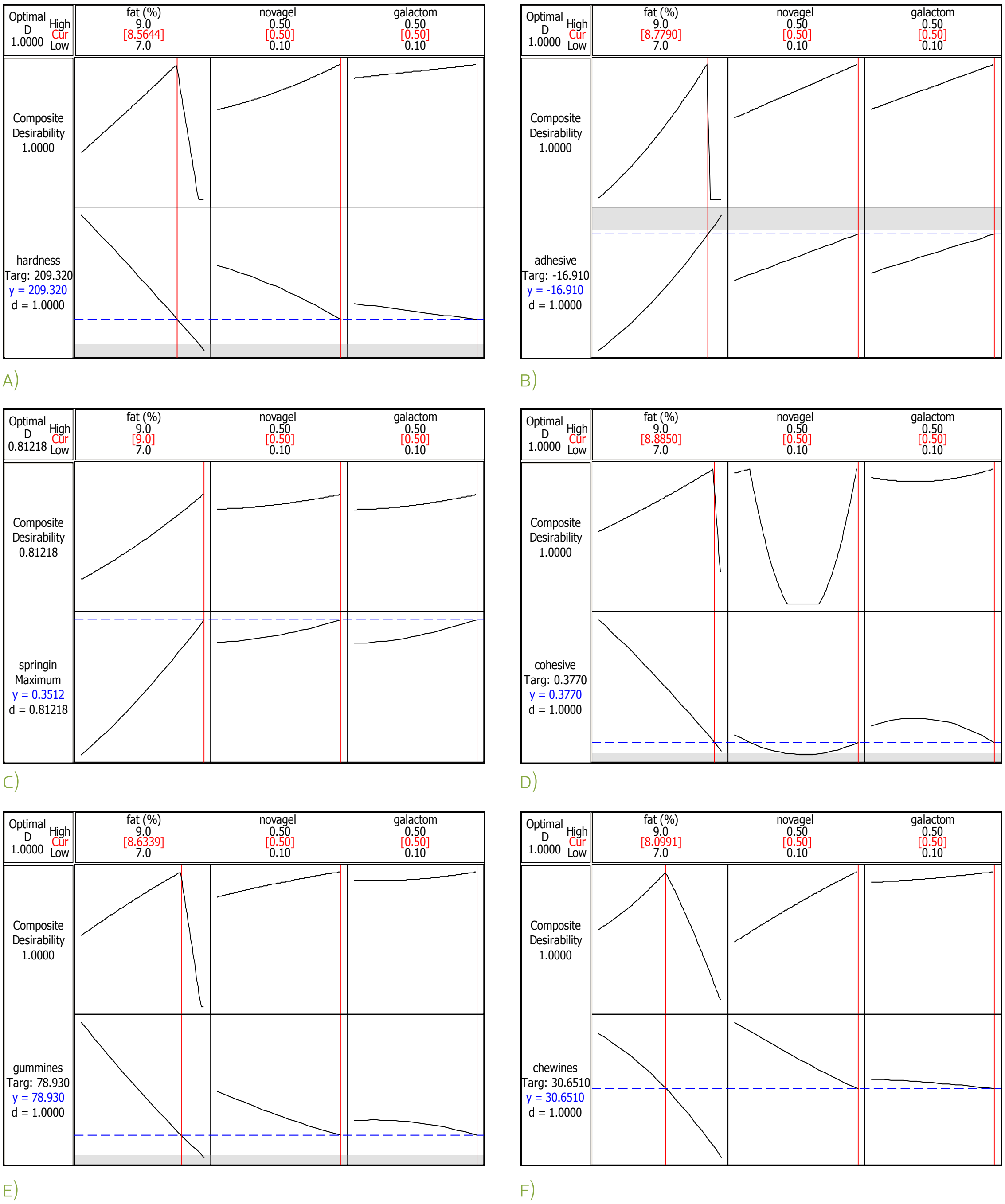

FIGURE 1. Single textural optimization of (a) Hardness (b) Adhesiveness (c) Springiness (d) Cohesiveness (e) Gumminess (f) Chewiness

The effect of fat, Novagel and Galactomannan on the Hardness of low-fat cheese

The hardness of the cheese samples is defined by the maximum force in the first biting and the sensorial power required to penetrate the milling teeth into the sample (Bourne, 1978). According to the results presented in Table 2, decreasing the fat significantly increases hardness in the treatments. Since low-fat cheese does not replace fat reduction by equal amounts of moisture, as a result, the amount of filler phase decreases in the matrix and causes the network to become denser. Consequently, a tighter texture is obtained (Romeih et al., 2002). Using Novagel and Galactomannan and increasing their concentration, the hardness of the treatments significantly decreases ($p\leq0.05$). The highest hardness (451.96 g) was observed in A_2 treatment (containing 7 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.1 % (w/w) Novagel), while the lowest hardness (171.02 g) was observed for C_4 (containing 9 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.5 % (w/w) Novagel). Those were significantly different comparing to the control sample. It's worth mentioning, C_2 sample containing 9 % (w/w) fat and 0.5 % (w/w) Galactomannan and 0.3 % (w/w) Novagel had no significant ($p>0.05$) difference in texture hardness comparing to the full fat control sample.

Justifying the role of hydrocolloids such as Galactomannan and Novagel for reducing the hardness of cheese, we can argue that these compounds demonstrate a good water-holding ability, which in turn causes water molecules to simulate the role of fat in the cheese matrix. Consequently, water molecules are put among protein molecules and prevent them from converging more closely together and creating more widely transversal links imply that the increased rigidity of the cheese (Romeih et al., 2002). The hydrocolloids absorb the water present in the cheese and through reducing the amount of free water, increase the hardness of the cheese (Rashidi, 2011). Adding hydrocolloids results in the increase of OH and other hydrophilic groups in the texture, which in turn enhances water absorption of the texture. This means that the protein network can store more water during clotting, which leads to the softness and springiness of the final texture. It's worth mentioning that water acts as a plasticizer for many bio-polymers due to its' small molecular size (Ghanbarzadeh, 2008). Should polysaccharide molecules with opposite charges be included in the protein chains, the interaction between protein and polysaccharide could possibly result in a larger gel network having higher water content captured in the protein network (Braga et al., 2006). A research of Abd karim et al. (1999) showed that there was an inverse connection between the amount of added Carrageenan hydrochloride in tofu formulation (produced by calcium sulfate and calcium acetate salts) and texture hardness. Since the concentration of hydrocolloids increases, the hardness of the texture decreases. Ghanbarzadeh et al. (2010) investigated the effect of pectin on some physical properties of soy cheese produced by calcium chloride and Glucono delta lactone coagulants. Adding hydrocolloids to tofu increased water holding capacity in the samples and the texture was softer than that of the control samples. If polysaccharide molecules with positive charges are placed among protein chains, a protein-polysaccharide reaction would probably result in a wider gel network and more water kept in the protein matrix (Chang et al., 2003). Hosseini-Parvar et al. (2015) accomplished a research regarding the microstructure, rheology and texture of cheese processed from coagulation casein and basil gum. They found that increasing the amount of basil gum increased elastic behaviour in the cheese and more hardness in the product, while reducing somewhat the melting properties of the cheese.

Aminifar et al. (2014) investigated the effect of xanthan and condensed milk protein on the hardness of low-fat brined cheeses, and found that the high absorption capacity of xanthan caused the reduction in the hardness of brined cheeses. Sipahioglu et al. (1999) investigated the effect of fat reduction and the use of Tapioca starch on Feta cheese. Their results stated that reducing the fat content of cheese from 19.8 % (w/w) to 12.5 % (w/w), its hardness rises from 47.6 to 73.9 N. The reason for this phenomenon is the existence of a continuous structure without fraction in low-fat cheeses. The most important factors of cheese hardness are such as relative humidity, protein and fat content. Romeih et al. (2002) and Koca and Metin, (2004) reported that using Simpless-D 100 (an alternative for lipid derived from water salt proteins) leads to reduced hardness of cheese. Esperan et al. (2011) investigated the effect of hydrocolloid carrageenan, Glucono delta-lactone and calcium chloride on the properties of soy bean cheese (tofu). They observed that adding hydrocolloids resulted in increased absorption of water in the texture, which was most probably due to the increase in OH- and other hydrophilic groups. Consequently, the protein network can retain more water during the cloth formation causing the softness and springiness of the final tofu texture. We should mention water acts as a softener for many biopolymers due to the small size of its molecules (Ghanbarzadeh, 2008).

Table 3 shows the results of hardness analysis of variance of low-fat cheeses texture containing different concentrations of Galactomannan and Novagel in accordance with RSM. According to the results, linear effects of fat, Novagel and Galactomannan on hardness changes were significant. Figure 1a shows the single optimization of hardness for the texture. The best formulation for reaching the texture hardness of low fat cheeses close to quality of the full-fat control sample was fat 8.56 % (w/w), Galactomannan 0.5 % (w/w), and Novagel 0.5 % (w/w). The hardness of the texture via the mentioned formulation predicted as 209.320 g with 100 % desirability.

The effect of fat, Novagel and Galactomannan on the Adhesiveness of low-fat cheeses

Based on the results of Table 2, by increasing lipid and hydrocolloids content, the adhesiveness significantly increased (p≤0.05). According to the results, the highest adhesiveness (-16.635 g.s) was observed in C_4 treatment (containing 9 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.5 % (w/w) Novagel) and the least adhesiveness (-23.855 g.s) was observed in both treatments of A_3 (containing 7 % (w/w) fat and 0.1 % (w/w) Galactomannan and 0.3 % (w/w) Novagel) and A_2 (containing 7 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.1 % (w/w) Novagel). The results confirmed that increasing the amount of fat in cheese and hydrocolloids, the structure of the protein matrix gets more open and weaker while increasing the adhesiveness. Reducing the fat, the protein matrix gets thicker and its adhesiveness decreases (Dimitreli and Thomareis, 2007). Saint-Eve et al. (2006) reviewed the effect of reducing the fat and salt amounts on the texture properties of ultrafiltrated cheese. The results showed that fat reduction caused reduction in adhesiveness of tested cheeses. For confirming the results, Koca and Metin, (2004) emphasized making use of Simpless-D 100 (An alternative for cheese water proteins) in low-fat cheese along with the higher adhesiveness in cheeses. Juan et al. (2013) produced low-fat cheese containing inulin and reported that by increasing the inulin contents, the adhesiveness of the samples significantly increased. Table 3 shows the analysis of variance of the texture adhesiveness of low-fat cheeses containing different concentrations of Galactomannan and Novagel in accordance with RSM. According to the results, linear effect of fat content had significant effect on adhesiveness changes. The linear effect of the Novagel and Galactomannan, the square and interaction effect of independent variable were not significant for adhesiveness changes. According to Fig. 1b, single optimization of texture adhesiveness (Y= -16.91 g.s) showed that the best formulation for reaching the textural adhesiveness of low-fat cheese close to the full-fat control sample achieved at fat 8.77 % (w/w), Galactomannan 0.5 % (w/w) and Novagel 0.5 % (w/w) with 100 % desirability.

Effect of fat, Novagel and Galactomannan on low-fat cheese Springiness

According to the results presented in Table 2, increasing the levels of fat, Novagel and Galactomannan, lead increasing springiness due to increasing moisture content and reducing hardness of tested cheeses. The highest rate of springiness (0.33550) after the control sample, belongs to the both treatments C_2 (containing 9 % (w/w) fat and 0.5 % (w/w) Galactomannan and 0.3 % (w/w) Novagel) and C_4 (containing 9 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.5 % (w/w) Novagel) that have the closest springiness to the control sample. The lowest rate of springiness (0.192 % (w/w)) was recorded for A_2 treatment (containing 7 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.1 % (w/w) Novagel).

Zisu and Shah (2005) considered the less springiness of low-fat cheese comparing to that of full-fat one related to the effect of increasing moisture and reducing the hardness of the cheese on the structure of the protein matrix and its weakness and finally reducing its ability to return to its original form after lifting the pressure. Korish and Elhamid, (2012) stated that the addition of pectin to Egyptian Kareish cheese causes decrease in springiness of samples comparing to that of the control sample. Rudan et al. (1999) stated that by decreasing the fat content of Mozzarella cheese the springiness significantly increased. Juan et al. (2013) accomplished an investigation of low-fat cheese containing inulin and reported that the springiness of the samples significantly increased with increasing the inulin content.

Table 3 presents the analysis of variance of the texture springiness of low-fat cheeses containing different concentrations of Galactomannan and Novagel in accordance with RSM. According to the results, the linear and square effects of fat, Novagel, and Galactomannan on springiness changes were significant ($p \leq 0.05$) and the interaction effects of fat, Novagel and Galactomannan on springiness changes were not significant.

Figure 1c shows a single optimization of textural springiness. The best formulation for reaching low-fat cheeses textural springiness close to the full-fat control sample is fat 9 % (w/w), Galactomannan 0.5 % (w/w) and Novagel 0.5 % (w/w). The springiness of the cheeses texture via the mentioned formulation predicted as 0.3512 with 81.21 % desirability.

The effect of fat, Novagel and Galactomannan on low-cheese Cohesiveness

The results in Table 2 showed that by increasing the fat, Galactomannan and Novagel content, cohesiveness significantly decreased. The use of Galactomannan and Novagel in low fat cheeses increased water absorption. Water molecules are located among the three-dimensional protein network and weaken the protein structure of the network and make the product softer (Fox et al., 2000). Consequently, cheese easily changed its shape as irreversibly as possible when under pressing (Zisu and Shah, 2005). The highest level of cohesiveness (0.54550) was observed in A_2 treatment (containing 7 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.1 % (w/w) Novagel) and the lowest cohesiveness (0.37050) after the control sample, were C_4 treatments (containing 9 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.5 % (w/w) Novagel). Along with the obtained results, Bryant et al. (1995) reported that decreasing fat value in Cheddar cheese caused an increase in the amount of cohesiveness. Hernández et al. (1999) pointed out that changing the texture cohesiveness in the gel produced from strawberry and gelatin pulp depends on the concentration of hydrocolloid consumed and fruit pulp.

Nebizadeh et al. (2016) investigated the effect of tragacanth gum and exopolysaccharide producing initiator on the characteristics of Cheddar cheese. They observed that the addition of tragacanth gum to low-fat cheese caused a significant decrease of cohesiveness comparing to that of the low-fat control sample. Koca and Metin, (2004) presented contradictory results for Kashar cheese. They declared that adding a carbohydrate fat replacer to the Kashar low-fat cheese increased the cohesiveness.

Table 3 shows the analysis of variance of the texture cohesiveness of low-fat cheeses containing different concentrations of Galactomannan and Novagel in accordance with RSM. The linear effect of fat and Novagel had a significant ($p \leq 0.05$) effect on changes in cohesiveness. Linear effects of Galactomannan and the square and interaction effects of independent variable on the cohesiveness changes are not significant ($p > 0.05$).

Fig. 1d shows single optimization of cohesiveness texture. The best formulation for reaching the cohesiveness of low-fat cheeses texture close to the full fat control cheese sample predicted in fat 8.88 % (w/w), 0.5 % (w/w) Galactomannan and 0.5 % (w/w) Novagel. The texture cohesiveness of the mentioned formulation predicted 0.3770 with 100 % desirability.

Evaluation of the effect of fat, Novagel and Galactomannan on Gumminess of the low-fat cheese

Table 2 shows that by increasing the amount of fat and fat substitutes (Galactomannan and Novagel) in low-fat cheese formulation, gumminess significantly decreased. The highest amount of gumminess (246.54) was found in A_2 treatment (containing 7 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.1 % (w/w) Novagel), and the lowest amount of gumminess (63.37 % (w/w)) was observed in C_4 treatment (containing 9 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.5 % (w/w) Novagel).

According to the obtained results, Saint-Eve et al. (2009) investigated the effect of reducing the fat and salt content of the ultrafiltration cheese. The results showed that lipid reduction causes increased gumminess. Mohammadzadeh Milani et al. (2017) investigated the effect of tragacanth gum on textural properties of Lighvan cheese. They found that the amount of gumminess of cheese samples decreased with increasing the amount of tragacanth gum. According to Romeih et al. (2002) and Koca and Metin, (2004) using Simpless-D 100 leads to reduced gumminess levels in cheese.

Table 3 shows the analysis of variance of the texture gumminess of low-fat cheeses containing different concentrations of Galactomannan and Novagel in accordance with RSM.

The linear effect of fat and Novagel on gumminess changes is significant ($p \leq 0.05$). The linear effects of Galactomannan and the square and interaction effects of fat, Galactomannan and Novagel on gumminess changes is not significant ($p > 0.05$).

Fig. 1e shows the results of single optimization of texture gumminess. The best formulation for reaching the low-fat cheeses texture gumminess close to full fat control cheese sample predicted in fat 8.6339 % (w/w), Galactomannan 0.5 % (w/w) and Novagel 0.5 % (w/w). The texture gumminess of the mentioned formulation predicted 78.93 with 100 % desirability.

Investigation of the effect of fat, Novagel and Galactomannan on the Chewiness of low-fat cheese

The results in Table 2, show that by increasing the amount of fat, Galactomannan and Novagel, chewiness significantly ($p \leq 0.05$) decreases. The presence of Galactomannan and Novagel in low fat cheese samples causes to absorb more water and, consequently weakens the body and the structural bond of cheeses. The highest chewiness (47.337) is related to A_2 (containing 7 % (w/w) fat and 0.3 % (w/w) Galactomannan and 0.1 % (w/w) Novagel. The lowest chewiness (21.256) observed in treatment C_4 (containing 9 % (w/w) Fat and 0.3 % (w/w) Galactomannan and 0.5 % (w/w) Novagel). Korish and Elhamid, (2012) has been reported that the chewiness of Egyptian Kareish cheese in presence of hydrocolloids decreased. Juan et al. (2013) mentioned that by reducing fat in cheese chewiness of cheese samples increased.

Table 3 shows the analysis of variance of the texture chewiness of low-fat cheeses containing different concentrations of Galactomannan and Novagel in accordance with RSM.

The linear effect of fat and Novagel changes have significant effect on chewiness variation. The linear effects of Galactomannan and the square and interaction effects of independent variable are not significant ($p > 0.05$) on chewiness variation.

Figure 1f shows the single optimization of chewiness. The best formulation for reaching the chewiness of low-fat cheeses close to the full-fat control sample predicted in fat 8.0998 % (w/w), Galactomannan 0.5 % (w/w), and Novagel 0.5 % (w/w). The texture chewiness of the mentioned formulation predicted 30.65110 with 100 % desirability.

Multiple optimization of low-fat cheeses in comparison with full-fat cheese

Figure 2 shows the multiple optimization of low-fat cheese textural properties. The best formulation for reaching the low-fat cheeses close to full fat cheese sample (control) predicted in fat

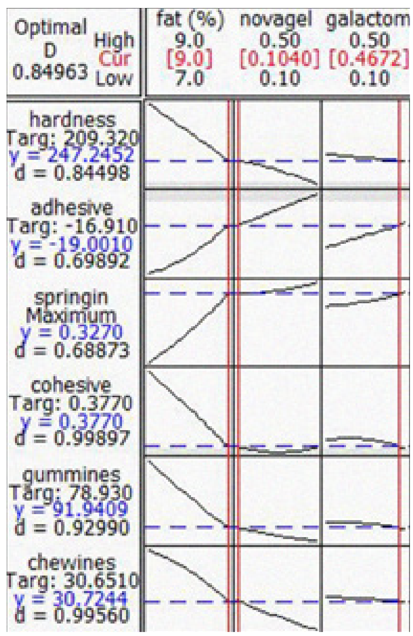

FIGURE 2. Multiple optimization of low-fat cheese textural properties containing different concentrations of Galactomannan and Novagel

9 % (w/w), Galactomannan 0.4672 % (w/w), and Novagel 0.1040 % (w/w). The predicted textural properties of the mentioned formulation were as follows, hardness = 247.2452 g, adhesiveness = -19.0010 g.s, springiness = 0.3270, cohesiveness = 0.3770, gumminess = 91.9409 and chewiness = 30.7244 with 84.96 % desirability. The predicted formulation practically produced. No significant difference was observed between the experimental and predicted textural properties. Therefore, the RSM was determined to be a valid method for optimization of the textural properties of the low fat ultrafiltrated cheese formulations.

Conclusion

The general aim of this research was to optimize the textural properties and to research in the possibility of producing low-fat cheese of (7-9 % (w/w)) fat, containing various concentrations of Galactomannan and Novagel (0.1-0.5 % (w/w)), evaluating textural properties of low-fat cheeses and comparing them with full-fat cheese. The effect of fat, Galactomannan and Novagel on the textural changes of low fat cheeses was significant ($p \leq 0.05$). Reducing the amount of fat in low-fat cheeses, the hardness, cohesiveness, gumminess and chewiness comparing to the control sample increased, while the adhesiveness, springiness and the overall acceptance score of low-fat samples decreased. The results showed that the textural properties of the treatment containing 9 % (w/w) fat and 0.5 % (w/w) Galactomannan and 0.3 % (w/w) Novagel were not significantly different with the control full fat cheese sample. Multiple optimization of low-fat cheese properties via the response-surface method showed that low-fat cheese containing 9 % (w/w) fat, 0.1 % (w/w) Novagel, and 0.46 % (w/w) Galactomannan creates the 84 % desirably textural properties similar to those of high-fat cheeses. The results of this research also showed by using Galactomannan and Novagel in low-fat cheese formulation, we are capable of producing low-fat cheese of favorable textural properties close to that of full-fat cheese.

Optimiranje i utvrđivanje parametara teksture niskomasnih sireva od ultrafiltriranig mlijeka s dodatkom galaktomanana i Novagel gume

Sažetak

Glavni cilj ovog istraživanja bio je optimizirati teksturu i utvrditi mogućnost proizvodnje niskomasnog sira (7-9 % (w/w)) od ultrafiltriranog mlijeka uz dodatak različitih koncentracija galaktomanana i Novagela (0,1-0,5 % w/w), te ih usporediti sa sirevima od punomasnog mlijeka. Prema dobivenim rezultatima, smanjenje udjela masti rezultira povećanjem tvrdoće, kohezivnosti, gumenosti i žvakljivosti testiranih uzoraka. S druge strane, dodatak galaktomanana i Novagela, te povećanje njihove koncentracije uzrokuje smanjenje tvrdoće, kohezivnosti, gumenosti i žvakljivosti sireva. Rezultati su također pokazali kako se prethodno spomenuti parametri teksture u uzorku s 9 % (w/w) masti, 0,5 % (w/w) galaktomanana i 0,3 % (w/w) Novagela nisu značajno razlikovali od istih kod kontrolnog uzorka sira, te je stoga navedeni uzorak niskomasnog sira odabran kao optimalan. Višestruko optimiranje parametara teksture niskomasnih sireva pomoću metode odzivnih površina (RSM) pokazalo je kako uzorak s 9 % (w/w) masti, 0,1 % (w/w) Novagela i 0,46 % (w/w) galaktomanana pokazuje 84 %-tno poklapanje s poželjnim svojstvima punomasnih sireva.

Ključne riječi: **galaktomanan, hidrokoloid, Novagel, ultrafilitrirano, niskomasni sir**

Conflict of interest

The authors declare no potential conflict of interest.

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