Middle-East Journal of Scientific Research 6 (4): 346-353, 2010
ISSN 1990-9233

The Effect of Xanthan Gum Using on Improving Texture and Rheological Properties of Iranian Low Fat White Cheese

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Abstract: In this research, the effect of xanthan gum in three concentrations of 0.02, 0.05 and 0.07 gram per each kilogram of skim milk, Containing 0.4% fat in producing Iranian white cheese was surveyed. Also, two control cheeses were prepared, that one of them was full fat cheese and made up from milk that containing 3.2% of fat and complete milk without gum and the other one was reduced fat cheese that was made up of skim milk, having 0.4% of fat without adding any gum. Results achieved from chemical, textural and rheological experiments showed the improvement in cheese texture together with Xanthan gum concentration increase. In this research, full fat control cheese had the least rheological and textural features extent of G′, G″, G*, σ and E showing that texture was soft and desirable. The cheese treated with Xanthan gum of 0.07 g had been so near to full fat control cheese, by increasing Xanthan extent concentration, textural and rheological features amount showed considerable decrease. Reduced fat control cheese had the most G′, G″, G*, σ and E features, indicating its hard texture and so undesirability. This study showed Xanthan gum desirability as a fat replace to decrease cheese energy-producing extent and also as a factor of texture improvement.

Key words: Low fat cheese · Rheology · Xanthan gum · Iranian white cheese

INTRODUCTION

Scientific and nutrition studies show that there is a relationship between much consumption of fat and various coronary heart diseases. Nowadays, continuous efforts to decline fat in food stuff, being used daily and widely. Iranian white cheese, as the major part of breakfast, is used considerably. Meanwhile, many attempts have been done to decrease fat in these important food materials; however, fat decline has bad effects such as texture hardness and Its undesirability. Certainly, producing low fat cheese, having suitable texture features, can help in decreasing coronary heart diseases.

Studies show that whenever cheese fat extent decrease, its humidity increases and protein plays much more role in cheese texture and structure. These changes make alternations in sensory, functional, microbial and chemical features of cheese. In microstructructures of low fat cheese, protein makes major part of it [1]. Texture defects like rubberiness and hardness emerge [2], because fat works as a major lubricant in cheese texture and when it decreases much more protein part is there in volume unit for deformation, due to stress occurring during chewing. To improve low fat cheese taste and texture, the common ways are followed [3-4]:

- Modification of common technologies of cheese production to keep moisture and using new technology.
- Using fat replacers to compensate cream texture decline.
- Choosing suitable starter culture.

Various researches have been done to improve cheese texture. Functional properties of modified starches

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of tapioca, lecithin in low fat feta cheese and the one with decreased fat have been surveyed [5]. Results convey that cheese with decreased fat, prepared with tapioca starch, had highest moisture and lowest protein and were harder, too. A mixture of starch and lecithin improved taste, texture and acceptance of low fat feta cheese and cheese with decreased fat.

A combination of microcrystalized cellulose with carrageenan and dry milk without fat was used for making cheddar cheese with 11% of fat [6]. Cheese structure was softened by interference of interaction of casein – casein by carrageenan and microcrystalized cellulose particles, similarly plays fat globule role in clotted matrix.

Researches show that using a pair of ExopolySaccharide producing starter cultures of MR-1C. Streptococcus thermophillus, lactobacillus delbrueckii sub spp bulgaricus increased moisture and melting features of low fat Mozzarella cheese [7], there is no sure replacement for fat yet, to provide taste and texture features out of fat in cheese.

The present study identified the effects of various concentrations of Xanthan gum as a fat replacer on rheological and textural properties (by measuring Uniaxial Compression and Dynamic Oscillatory measurements) and on color (determined by Hunter–Lab System) and chemical features of Iranian white cheese after 60 days of ripening period in brine.

MATERIALS AND METHODS

Treatments, Cultures, Rennet and Xanthan Gum: To study the effects of various concentrations of Xanthan gum, five treatments were prepared, that from now on they are recorded in this article in encoded way. All treatments were prepared three times: full fat control cheese produced with complete milk = FFC, Reduced fat control cheese or control cheese with decreased fat = RFC, reduced fat cheese with 0.02 g of Xanthan gum per each kilogram of producing milk (skim milk with 0.04% fat) = X1, reduced fat cheese with 0.05 g of Xanthan gum per each kilogram of producing milk (skim milk with 0.04% fat) = X2, reduced fat cheese with 0.07 g of Xanthan gum per each kilogram of producing milk (skim milk with 0.04% fat) =X3. Cheese batches were manufactured by 7 kg of standardized milk for each treatment.

Consumed starter culture was FRC – 65, it was dairy culture of Hansen Co. Denmark. FRC – 65 included lactococcus lactis sub spp cremoris sub spp lactis, streptococcus thermophillus and lactobacillus delbrueckii sub spp bulgaricus.Chymosin derived by fermentation of Aspergillus niger Var. awamori (CHY – Max standard rennet, Hansen Dairy Co. Denmark), was used as a clotter with 0.025 concentration per one kilogram of milk.

Consumed rennet was diluted 30 fold with cold water and then added to each 7 kg batch of milk.

Xanthan gum was a product from Aldrich Company (Xanthan gum, 500g ALDRICH). In addition, we did not use Xanthan gum in producing full fat cheese as a control group and reduced fat control was lack of gum and included 0.4% fat.

Cheese Making Procedure: Raw skim milk contained 0.4% of fat and it was used for producing fat free cheese. First of all, 7kg of milk from each treatment were pasteurized in a pasteurizator (MKII, Armfeild Ltd, Ring wood, Hampshire, UK model FT20). Then it was poured into production vat. Various concentrations of xanthan gum were solved in 200cc water, warmed to 65°C, by a mixer. Next it was kept in Benmary 40°C until all gum particles were solved completely [8]. Finally it was poured into vat containing milk. To mix these two parts uniformally and completely, it was let to stir the milk calmly for 20 min. During this time milk's temperature was 34°C, while 0.15 g of Cacl for each kilogram of milk was added and starter culture with 0.04 g concentration was inoculated to each kilogram of milk and kept at this temperature for 55 min to have enough opportunity for starter's activity before the addition of rennet.

Then the rennet, to the mentioned concentration, was added for 45 min to form clotting. The clottings, next, were cut in to 1cm cubes and kept release for 10 min, then with a gradual tone the cubes were stirred for 10 min to quicken cheese draining from them. After empetizing whey, the clottings were poured in to press especial molds and were pressed for 2.5 h. Press pressure was increased little by little during first 1.5 h and reached to 2.9 kpa, then it was kept until end of pressing.

In next stage, pressed clottings were cut into 6cm × 6cm × 4cm pieces and were kept in 23-25°C for 2h. Then they were put in airtight plastic containers and their surfaces were covered with 13% of brine. It should be mentioned that this brine, before application was pasteurized in 80°C for 10 min and after rapid cooling through passing a clean cloth, it was purified and adjusted to PH 4.45 by addition 99% Lactic Acid. Then the containers were potted and kept in 5-6°C until doing the related experiments. Full fat cheese was produced from milk including 3.2% of fat and in the same way as fat free cheese was produced, al bite without adding any gum. All experiments were done after 60 days of ripening period.

Chemical Experiments: Milk and cheese samples' pH was determined by digital pH meter (microprocessor pH meter model pH 537, WTW, weilheim, Germany). Cheese was analyzed for moisture content by vacuum oven [9]. The fat content of milk and cheese samples was determined by the Gerber method and their total protein contents were determined by measuring total nitrogen using the kjeldahl method [9] and converting it to protein content by multiplying by 6.38. Total solid of milk were determined by drying 5g of the sample at 100°C in an oven for at least 4h. Milk features like protein content, fat, density, SNF and others were identified by milk analyzer machine (Eko Milk).

Measuring soluble nitrogen (SN) and nitrogen solved in three chloride acetic acid (NPN) was performed by standard method. Titrable acidity was measured on the basis of lactic acid (W/W). All chemical measurements were repeated at least three times.

Rheological Experiments

Uniaxial Compression: Uniaxial compression, the simplest fundamental test, was done by the universal Experiment Machine (HTE) (Hounsfield test, UK S-Series Bench UTM model H 5k-S, Redhill, Equipment Ltd).This machine was equipped with loadcell of 500N. To do the experiment, a flat piston with 49 mm diameter was connected to machine's forwarding front. Cheese pieces were cut into cylinders of 25mm diameter and 10mm height in 6°C. To prevent losing their moisture quickly, they were put in airtight containers and potted.Cheese samples were selected from depth of at samples have temperature equal with room temperature, they were kept in room at least 4 hours before testing. The samples were pressed in uniaxial way with forwarding front speed of 50 mm/min to 57% of the sample's primary height in amunch. Rupture stress was calculated from dividing recorded force in rupture point of deformation cure into sample's primary surface and young (elastic) modulus as secant modulus in rupture point [11-12].

Dynamic Rheological Measurement: Small amplitude oscillatory shear measurements were performed with a Universal Dynamic spectrometer, Paar physica UDS 200 rheometer (physica Messtechnik GmbH, Stuttgart, Germany).The measuring geometry consisted of 2 parallel plates with a diameter of 25 mm and 1-mm gap size (sample thickness). Samples were cut at least 1cm deep into the cheese blocks at 6°C. These samples were immediately placed in small airtight plastic containers and equilibrated at room temperature (22±1°C) for at least 4h.

Excessive cheese was trimmed of carefully with a razor blade and the sample allowed resting for 20 min on the rheometer to allow stresses induced during sample handling to relax. Frequency was set at 0.1 Hz and amplitude was varied between 0.1 to 10% resulting in a strain sweep test (Madadlou et al. 2006). Calculated parameters were: G' (Storage modulus), G" (Loss modulus), G* (complex modulus), It is relationship between G' & G" (1,18). In this study, these three parameters have been reported.

Color Analysis: Cheese Various treatments colors during ripening was quantitatively determined using a Hunterlab colorimeter system (Hunter lab, Dp-9000, Hunter Associates laboratory, Inc. Reston, VA), in which L and b values correspond to whiteness and yellowness (28), respectively color measurements were performed in triplicate for each treatment at different site.

Sensory Evaluation: Cheese samples, encoded randomly, were evaluated by a group of acceptance sensory. Acceptance group's panels included 40 individuals in age range of 21-35, 25 males and 15 females. They were a group of food science and technology students in Urmia University and its staff. Before evaluation, they were asked to full fill a questionnaire including questions on sex, age and times of consuming cheese (non-consuming in one month, less than one time in a month, 2-4 times in a month, 5-6 times in a month and more than 6 times in a month). Those panels in which cheese consumption was 2-4 times in a month or less than that were put a side from data analysis.

Cheese in terms of appearance, texture, taste and general acceptance were evaluated according to hedonic scale of 5 scores (1 = the most undesirable, 5=the most desirable). Cheese pieces were cut into pieces with standard dimensions for biting (1cm × 1cm × 1.3cm) and were put into airtight plastic containers for 2 hours before evaluation to reach heat balance of room [13]. Panels used water to wash their mouth between samples treatments. Sensory evaluation was done after 60 days of ripening period.

Statistical Analysis: The experiment was acted in three times and in a completely randomized design, sensory evaluation, also, was performed in terms of randomized blocks design. Data analysis and evaluation were done by spss software in 5% probability level to determine difference between means. To plot the related diagrams, spss software was used.

RESULTS AND DISCUSSION

Chemical Combination and Features: Chemical combination and features of milk, used to produce various treatments of milk and chemical features of produced cheese are shown in Tables 1-3.

Matching with other researchers' findings, we noticed that when fat content declines, moisture and protein of milk increasing considerably. But there was not any difference in pH degrees of milks.

Cheese with reduced fat had much more protein and moisture than full fat cheese. Also, fat decline led to moisture decline in nonfat substance so that ratio of moisture to protein matched with other researcher's findings [13-15]. Difference between moisture rate of full fat and low fat cheese was probably due to difference in their proteins, so that high extent of protein in cheese with reduced fat may be together with water absorption promotion in protein matrix [15-16] and as a result lead to moisture increase in them. In casein matrix of cheese texture, fat and moisture perform as full fillers [17].

Whenever fat content decreases, moisture cannot replaced with the same amount of lost fat; therefore, general volume of full filler decreases, declines moisture in nonfat substances and ratio of moisture to protein. When Xanthan extent increases in fat free cheese, protein part percent decreases, because of cheese moisture increase due to this fact that Xanthan Likes to absorb water, it indicates that water extraction decreases during cheese production. Protein part decrease is as a result of proteolysis increase. Therefore, ratio of moisture to protein, which is an important factor in producing cheese, increase in cheese produced by Xanthan. Producing low fat cheese, as it was mentioned, decreases ratio of moisture to protein, so that cheese texture becomes hard and undesirable [17]. Therefore, to improve reduced fat cheese texture properties, we should increase ratio of moisture to protein [18].

Table 1: Properties of consumed milk for producing cheese

	Milk type	
	Low fat	Full fat
Fat percent	0.4[b]	3.2[a]
Moisture	91.5[a]	89.4[b]
Protein	3.2[a]	3.15[b]
pH	6.58[a]	6.59[a]

*Means, having different superscript, showed meaningful difference (less than 0.05) with one another.

In this research we achieved this goal by increasing Xanthan concentration and as a result by increasing moisture extent and decreasing protein part.Cheese moisture increased by Xanthan concentration promotion, that it's because of cheese proteolysis due to micro flora presence [19] and high amount of chymosin [20] and moisture absorption increase by Xanthan, as it Likes water absorbing.

In this research, whenever Xanthan concentration increases, soluble nitrogen (SN/TN) and non protein nitrogen (NPN/TN) increase, it indicates that proteolysis was much more and had led to soft texture of the cheese due to cheese moisture increase and ratio of moisture to protein was more.Moisture increasing among various treatments with decreased fat results in fat content decrease in cheese composition, so that whenever fat decreases, fat percent in dry matter decreases as well. This issue is clearly obvious in cheese treated with Xanthan. In comparing between full fat control cheese and reduced fat control cheese, moisture in nonfat substance (MNFS) of full fat cheese is higher. Among cheese with decreased fat, whenever Xanthan gum

Table 2: Measured parameters in different treatments of cheese

M:P	Protein recycling percent	Fat recycling percent	Protein (%)	Fat (%)	Moisture (%)	Cheese Variety
5.5733[c]	3.8300[c]	3.9833[d]	12.2667[c]	12.7500[a]	68.43333[e]	FFC
4.8467[e]	4.6223[a]	8.7667[a]	14.5667[a]	3.5067[b]	70.64667[d]	RFC
5.3733[d]	4.2800[b]	7.5000[b]	13.5000[b]	3.0000[c]	72.56667[c]	X1
7.4033[b]	3.2317[d]	4.2700[c]	10.1833[d]	1.7067[d]	75.43333[b]	X2
8.1523[a]	3.0260[e]	3.5500[e]	9.5333[e]	1.4200[e]	77.73333[a]	X3

Table 3: Measured parameters in different treatment of cheese

NPN/TN	SN/TN	Acidity in basis of Lactic acid	pH	Output (%)	MNFS	FDM (%)	Cheese Variety
2.9267[e]	3.1767[d]	0.4000[d]	5.8067[a]	17.2573[a]	40.7777[e]	40.3967[a]	FFC
8.5267[c]	13.6000[b]	0.4500[c]	4.9800[e]	13.3067[a]	62.1767[d]	11.9500[b]	RFC
4.2900[d]	9.6167[c]	0.4567[c]	5.3600[b]	12.71[a]	64.6200[c]	10.9400[b]	X1
9.6233[b]	13.3333[b]	0.5800[b]	5.2467[c]	16.3167[a]	70.1900[b]	6.9400[c]	X2
9.9633[a]	15.5500[a]	0.6300[a]	5.0400[d]	16.8267[a]	72.7700[a]	6.3733[c]	X3

* Means, having different superscript, showed meaningful difference (less than 0.05) with one another.

concentration increases, MNFS extent will increase too. One of the most important ways of improving texture features of low fat cheese is moisture rate promotion, so that ratio of moisture to protein and or moisture in nonfat substance will be equal or more than that of full fat cheese [21].

Fat and protein recycling got considerable effects from fat extent. In this study, when fat extent decreased between full fat control cheeses and reduced fat control cheese, fat recycling increased dramatically, protein recycling percent increased too, but with a less ratio than fat recycling percent. In cheese treated with Xanthan gum, when Xanthan gum concentration increases, fat and protein recycling percent decreases.

Fat extent decline led to pH decline and acidity increase between two samples of full fat control cheese and reduced fat control cheese. In addition, in samples with decreased fat, Xanthan gum concentration increase results in acidity promotion and pH decline, it can be said that its reason is severe lipolysis and complete conversion of lactose to lactic acid in reduced fat control cheese and those treated with Xanthan. When fat extent in goes down, cheese production output declined considerably. During cheese production, milk fat is trapped in casein matrix (Rudan et al. 1997); although, moisture is replaced of present fat [22].

Total output decline (one kilogram of cheese per one Kilogram of milk) in cheese production from low fat milk is unavoidable [23], since the extent of added moisture would not be equal with decreased fat amount [24-25], therefore the extents of milk's fat and casein, as the main compositions determining output rate, will decrease. Among cheese treated with decreased fat, Xanthan gum concentration increase makes cheese producing output increase because of more durability of water in cheese, that of water absorbing feature of this gum. However there was no meaningful difference among treatments.

Rheological Analysis

Uniaxial Compression: Uniaxial compression parameters of treatments after ripening period are shown in Table 4. To understand texture features of treatments, two parameters, stress in rupture point and young (elastic) modulus of cheese were surveyed. Stress in rupture point has direct relationship with cheese hardness [26-27], that is, the more stress in rupture point, the more hardness and vice versa.

Elastic modulus or elasticity is for showing the relationship between stress and strain of foodstuffs [28], likewise stress in rupture point, the more elastic modulus, the more hardness, the cheese texture has. In this study, FFC had the least stress in rupture point and the least elastic modulus (E), showing its soft and desirable texture, while RFC had the most stress in rupture point and the most elastic modulus (E) or young modulus, indicating its hard and undesirable texture.

Table 4: Means of uniaxial compression for Iranian white cheese treated by Xanthan gum (in basis of kpa)

E (kpa)	σ (kpa)	Cheese Variety
14.04035^{c}	7.051068^{d}	FFC
175.0181^{a}	55.39333^{a}	RFC
22.78667^{b}	11.44119^{b}	X1
17.82000^{c}	10.83655b^{c}	X2
15.01100^{c}	9.044128^{c}	X3

Table 5: Amounts of G′,G″,G* from rheometer machine (in basis of kpa)

G′	G″	G*	Cheese Variety
28.8873^{b}	9.5576^{d}	27.2555^{b}	FFC
305.7803^{a}	111.3805^{a}	284.7018^{a}	RFC
99.9919^{b}	30.7058^{b}	95.1601^{b}	X1
80.7648^{b}	21.8450^{bc}	77.7530^{b}	X2
48.0059^{b}	12.7957^{cd}	46.2691^{b}	X3

* Means, having different superscript, showed meaningful difference (less than 0.05) with one another

Whenever Xanthan gum concentration increases young (elastic) modulus (E) and stress in rupture point decrease and come near to full fat cheese, X3 was so close to fullfat cheese.

Protein extent decrease during ripening period can be the reason of cheese hardness decrease in Horne model [29]. Micellar calcium phosphate does not play just the role of connector of casein microclusters, but due to positive load, acts as a neutralizer. These positive loads neutralize phosphoserine negative loads in interaction point between casein hydrophobic regions and as a result make their connection possible [30-31]. During cheese ripening and also by increasing Xanthan gum concentration with pH decline, calcium phosphate turns in to solution and by decreasing calcium extent connected to casein micells, rejecting forces between caseins increase [30] and make cheese structural bonds weaker. This phenomenon can be the reason of stress decline in cheese rupture point and as a result its softness due to Xanthan gum concentration increases.

Dynamic Rheological Measurement: Lower level of storage modulus (G'), like stress, has a relationship with Iranian white cheese hardness [25]. The more G', G" and G*, the more hardness and undesirability of texture. Fat decrease in surveyed cheese, increased G', G" and G*

Table 6: Amounts of b-Value and L-Value in different treatments of cheese

L-Value	b-Value	Cheese Variety
21.7333^{e}	1.9500^{a}	FFC
22.3700^{a}	1.4667^{d}	RFC
21.9533^{d}	1.9000^{b}	X1
22.1233^{c}	1.8633^{b}	X2
22.1733^{bc}	1.8167^{c}	X3

Table 7: Amounts of data given by panels

General acceptance	Taste	Texture	Appearance	Cheese Variety
4.8500^{a}	4.5128^{a}	4.6000^{a}	3.7250^{a}	FFC
1.3250^{d}	1.1538^{e}	1.8500^{d}	2.1000^{b}	RFC
4.1250^{b}	2.8974^{c}	3.2500^{bc}	3.7250^{a}	X1
3.2500^{c}	2.1795^{d}	2.9000^{c}	3.6000^{a}	X2
3.0000^{c}	3.3846^{b}	3.6750^{b}	3.5500^{a}	X3

* Means, having different superscript, showed meaningful difference (less than 0.05) with one another

considerably, surely due to moisture part share. Moisture decline in nonfat substance and ratio of moisture to protein in reduced fat control cheese made the product be semisolid, but because of Xanthan gum concentration increased, G', G" and G* decreased and became like of full fat cheese, as a result of moisture increase and cheese softness. Of course, X3 was so close to full fat cheese.It should be said that, since the ratio of remained rennet to casein, in cheese with high moisture rate to those with low moisture, is more [31], their softness level is too much as well.

Color Evaluation: In Table 6 results of color evaluation of different cheese treatments during ripening are shown. The scattering of light by any system is related to its heterogeneity at the molecular [23] and microstructural levels [27]. In a solid material such as cheese, light penetrates the superficial layers and is scattered mainly at the interfaces of milk fat globules [22] and the edges of whey pockets [28].

L–Value and b–Value were two criteria of color evaluation, indicating whiteness and yellowness of cheese respectively [27]. In a comparison made between full fat control cheese and reduced fat control cheese, it was cleared that full fat cheese had more yellowness and less whiteness, in addition to Xanthan gum concentration increase leads to L-Value promotion and b-Value decreasing, i.e. cheese whiteness increases.

The reason of whiteness increase in cheese treated with Xanthan is promotion of cheese whey pockets that is whenever Xanthan concentrates, the number of whey pockets increases.

Sensory Evaluation: Table 7 shows sensory evaluation results. We observed what we expected. Full fat cheese had the most scores in any terms. Fat content decline had affected taste, texture and general acceptance of Iranian white cheese. RFC had the least privileges in any terms. Among cheese treated with Xanthan, X3 was the most preferred one in taste and texture. X1, also, had the most privileges in terms of appearance and general acceptance. Perhaps a suitable texture, neither hard nor soft and its appearance with highest privileges was the reason.

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Abbreviation:

MNFS : Moisture in nonfat substance,
M:P : Ratio of moisture to protein, FDM: Fat in dry matter,

$$\text{Fat recycling Percent:} \frac{\text{Fat content in cheese}}{\text{Fat content in raw milk}}$$

$$\text{Protein recycling Percent :} \frac{\text{Protein content in cheese}}{\text{Protein content in raw milk}}$$

SN : Soluble nitrogen,
NPN : Non protein nitrogen,
TN : Total nitrogen,
FFC : Full fat control cheese produced with complete milk that containing 3.2% of fat without gum,
RFC : Reduced fat control cheese that was made up of skim milk, having 0.4% of fat without adding any gum,
X1 : Reduced fat cheese with 0.02 gram of Xanthan gum per each kilogram of producing milk (skim milk with 0.04% fat),
X2 : Reduced fat cheese with 0.05 gram of Xanthan gum per each kilogram of producing milk (skim milk with 0.04% fat),
X3 : Reduced fat cheese with 0.07 gram of Xanthan gum per each kilogram of producing milk (skim milk with 0.04% fat),
G' : Storage modulus
G" : Loss modulus,
G^* : Complex modulus,
σ : Stress in rupture point,
E : Elastic modulus or young modulus