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

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**Abstract:** In this research, the effect of Arabic gum in three concentrations of 0.25, 0.5 and 0.75 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 good improvement in cheese texture by increasing Arabic gum's concentration to 0.5 gr. In this research, full fat control cheese had the least textural and rheological features extent of G′, G″, G*, σ and E that texture was soft and desirable. The cheese treated with 0.5 g of Arabic gum was close to full fat control cheese. However, by increasing Arabic gum's concentration to 0.75gr, these indices showed high promotion and were close to reduced fat control cheese. Reduced fat control cheese had the most of G′, G″, G*,σ and E indicating its hard texture and so undesirability. One can conclude that Arabic gum in low level concentration can be used as a fat replacer to decline energy-producing feature and its texture improvement as well.

**Key words:** Low fat cheese · Rheology · Texture · Arabic 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 and doing to decline fat in food stuff, is 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 of tapioca, lecithin in low fat feta cheese and the one with decreased fat have been surveyed [5]. Results convey

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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 Arabic 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 Arabic Gum:** To study the effects of various concentrations of Arabic gum, five treatments were prepared, that from now on they are recorded in this article in encoded way. All treatments were prepared th8ree 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 0.2 g of Arabic gum per each kilogram of producing milk (skim milk with 0.04% fat) = A1, reduced fat cheese with 0.5 g of Arabic gum per each kilogram of producing milk (skim milk with 0.04% fat) = A2, reduced fat cheese with 0.75 g of Arabic gum per each kilogram of producing milk (skim milk with 0.04% fat) = A3. 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 lactic, 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. Arabic gum was a product from Merck Co. Germany (Arabic gum Merck – Germany 1kg). In addition, we did not use Arabic 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, including 0.4% of fat, was used for producing fat free cheese. At first 6 kg of milk from each treatment was pasteurized in a continuous way in 75°C for 15s inside a pasteurizator. Rest of the milk (1 kg) was warmed to 35°C and different concentrations of Arabic gum were solved in it by a mixer and then were pasteurized by continuous pasteurization in a similar way. Then both parts of the milk were mixed together and were poured in to production vat (MKII, Armfeild Ltd., Ringwood, Hampshire, UK, model FT20). To mix these two parts uniformly 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.

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 [8] 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) [8]). 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.

**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 [1]. Calculated parameters were: G' (Storage modulus), G" (Loss modulus), G* (complex modulus), It is relationship between G' & G" (2, 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, 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. Panels used water to wash their mouth between samples treatments. Sensory evaluation was done after 60 days of ripening period [9].

**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.

Table 1: properties of consumed milk for producing cheese

| | Milk type | |
|---|---|---|
| | Low fat | Full fat |
| Ffat 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

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 non fat substance so that ratio of moisture to protein matched with other researcher's findings [10-11]. 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 [12] and as a result lead to moisture increase in them.In casein matrix of cheese texture, fat and moisture perform as full fillers [13].

Whenever fat content decreases, moisture can not replaced with the same amount of lost fat; therefore, general volume of full filler decreases, declines moisture in non fat substances and ratio of moisture to protein. When Arabic gum concentrates to A2 level, protein part percent decreases, but when its concentration goes up to A3 level, the state is converted vice versa, i.e. protein part percent increases, indicating less proteolysis, also ratio of moisture to protein in A3 decreases, too.

Perhaps this phenomenon relates to especial structure of Arabic gum that in high concentrations leads to bounding of water; also, it results in viscosity increases.

Therefore, ratio of moisture to protein, as an important factor in producing cheese, in cheese produced with Arabic gum has been increased in level A1 and A2, but by promotion to level A3, this rate is declined. By producing low fat cheese, as it was mentioned, ratio of moisture to protein declines; hence, cheese texture gets rough and undesirable [13]. This issue happens in A3, too. Hence to improve cheese texture features with decreased fat, the goal is to increase ratio of moisture to protein [14]. In this study, when Arabic gum's concentration promotes to level A2 and as a result when moisture increase and protein part declines, we get this goal.

By increasing concentration of Arabic gum in levels A1 and A2, the extent of soluble nitrogen (SN) and non protein nitrogen (NPN/TN) decline, showing rigidity promotion of cheese texture due to moisture decrease and ratio of moisture to protein, too.

By increasing Arabic gum's concentration, cheese fat contents show increasing trend, this phenomenon has show increase in levels A1 and A2, but a considerable promotion in level A3. Likewise, fat percent in dry matter shows a little increasing at first and a high promotion in level A3. This issue indicates less lipolysis during promotion of Arabic gum's concentration.

Comparing full fat control cheese and reduced fat control cheese we notice that moisture rate in non fat substance (MNFS) of full fat cheese is much more. MNFS of cheese increases when Arabic gum concentrates in levels A1 & A2, but its extent decreases in level A3.

Table 2: Measured parameters in different treatments of cheese

| M:P | Protein Recycling Percent | Fat Recycling Percent | Protein | Fat (%) | Moisture (%) | Cheese Variety |
|---|---|---|---|---|---|---|
| 5.5733 [b] | 3.8300[d] | 3.9833[c] | 12.2667[d] | 12.7500[a] | 68.43333[d] | FFC |
| 4.8467[c] | 4.6223[b] | 8.7667[a] | 14.5667[b] | 3.5067[b] | 70.64667[c] | RFC |
| 5.6577[b] | 4.1010[c] | 1.25[e] | 12.9333[c] | 0.5000[e] | 73.200000[b] | A1 |
| 7.12[a] | 3.3733[e] | 2.5[d] | 10.6333[e] | 1.0000[d] | 75.73333[a] | A2 |
| 3.4837[d] | 6.0600[a] | 7.5[b] | 19.1000[a] | 3.0000[c] | 66.44667[e] | A3 |

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[e] | 0.4000[d] | 5.8067[a] | 17.2573[a] | 40.7777[e] | 40.3967[a] | FFC |
| 8.5267[a] | 13.6000[c] | 0.4500[b] | 4.9800[e] | 13.3067[a] | 62.1767[c] | 11.9500[b] | RFC |
| 4.0900[c] | 33.3800[b] | 0.4767[ab] | 5.6400[b] | 15.0767[a] | 71.8300[b] | 1.8600[e] | A1 |
| 4.7867[b] | 35.4167[a] | 0.4900[a] | 5.1500[d] | 16.5700[a] | 72.6033[ab] | 4.1200[d] | A2 |
| 3.5267[d] | 10.0667[d] | 0.3400[e] | 5.49[c] | 17.0100[a] | 60.5000[d] | 8.9397[c] | A3 |

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

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

| E (kpa) | σ(kpa) | Cheese Variety |
|---|---|---|
| 14.04035[e] | 7.051068[e] | FFC |
| 175.0181[a] | 55.39333[a] | RFC |
| 74.20333[c] | 35.94077[c] | A1 |
| 53.90067[d] | 25.06381[d] | A2 |
| 98.48267[b] | 49.43830[b] | A3 |

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

| G* | G″ | G′ | Cheese variety |
|---|---|---|---|
| 28.8873[d] | 9.5576[e] | 27.2555[d] | FFC |
| 305.7803[b] | 111.3805[c] | 284.7018[b] | RFC |
| 289.9815[b] | 136.0633[b] | 256.0843[bc] | A1 |
| 196.8950[c] | 70.6822[d] | 183.7381[c] | A2 |
| 929.8107[a] | 268.2753[a] | 890.2014[a] | A3 |

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

| L-Value | b-Value | Cheese variety |
|---|---|---|
| 21.7333[d] | 1.9500[b] | FFC |
| 22.3700[a] | 1.4667[e] | RFC |
| 22.2200[b] | 1.6700[d] | A1 |
| 21.9500[c] | 1.7500[c] | A2 |
| 21.0567[e] | 2.0467[a] | A3 |

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

One of the most important ways of improving texture features of low fat cheese is to increase rate to an extent in which ratio of moisture to protein and or moisture in non fat substance equals with that of full fat cheese or more than that [15].

Fat and protein recycling get effects dramatically from fat extent. In this study, when fat extent between full fat cheese and the one with reduced fat declines, fat recycling increased considerably.

Protein recycling percent showed promotion as well, but with a rate less that fat recycling.

Increasing Arabic gum concentration leads to fat recycling percent, but protein recycling percent to level A3 decreases and then in level A3 indicates promotion.

Fat extent decrease caused pH decline and acidity increasing between two samples of full fat control cheese and reduced fat control cheese. When Arabic gum concentrates to level A3, we observe pH decline and acidity increasing but in level A3, the opposite case is true. The main reason of pH decrease in level A1 and A2 is due to lipolysis and complete conversion of lactose into lactic acid.

Decreasing fat extent in cheese, cheese producing output goes down very much. During cheese production, milk fat is trapped in casein field [15-16].

Although moisture is replaced with fat present in milk [17]; Total output decline (one kilogram of cheese per one Kilogram of milk) in cheese production from low fat milk is unavoidable [17], since the extent of added moisture would not be equal with decreased fat amount [18-19].

Therefore, fat and casein of milk, as major compositions determining output, decrease. Among treatments of cheese with decreased fat, Arabic gum's concentration promotion increases cheese production output, as much more water remains in cheese because this gum likes to absorb water.

Although there was not any meaningful difference; in general, 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 [19-20] 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 (Mohsenin et al., 1986), 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.

When Arabic gum's concentration increases to level A2, elastic or young modulus and stress in rupture point decreased, then in level A3 it showed considerable increasing. This fact conveys that its high concentrations make texture hard.

Increasing gum's concentration to level A2 and decreasing pH turn cacl into a solution. When calcium extent, connected to casein micelles, decreases, rejecting forces between caseins increase [20-23] and result in weakening structural bonds of cheese. This phenomenon can be a reason for stress decline in cheese rupture point and as a result in its softness until level A2. Arabic gum's concentration increasing until A3 level because of viscosity increase due to this gum's performance in high concentration and increase of structural bonds make cheese have hard texture.

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[e] | 1.1538[d] | 1.8500[c] | 2.1000[d] | RFC |
| 3.9250[b] | 2.7179[b] | 2.9000[b] | 2.8500[bc] | A1 |
| 3.1000[c] | 2.0000[c] | 3.1500[b] | 3.1750[ab] | A2 |
| 2.4250[d] | 1.6154[d] | 2.0000[c] | 2.3750[c] | A3 |

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

**Dynamic Rheological Measurement:** Lower level of storage modulus (G'), like stress, has a relationship with Iranian white cheese hardness [16]. The more G', G" and G*, the more hardness and undesirability of texture. Fat decrease in surveyed cheese, increased G', G" and G* considerably, surely due to moisture part share. Moisture decline in non fat substance and ratio of moisture to protein in reduced fat control cheese made the product be semisolid, but because of Arabic gum concentration increase to level A2, G', G" and G* decreased and were near to full fat cheese, as a result of moisture extent promotion and cheese softness. However A3 had lots of G', G" and G*, indicating A3 cheese texture's hardness.

It must be said that since the ratio of remained rennet to casein in cheese with high moisture is much more than cheese with low moisture [23], their softness is much too.

**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 [24] and microstructural levels [25].

In a solid material such as cheese, light penetrates the superficial layers and is scattered mainly at the interfaces of milk fat globules [26] and the edges of whey pockets [27].

L–Value and b–Value were two criteria of color evaluation, indicating whiteness and yellowness of cheese respectively [28]. 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, when Arabic gum concentrates, b–Value goes up and L-Value comes down; therefore cheese treated with Arabic gum have more yellowness and are similar to full fat control ones in terms of color.

The reason of this phenomenon is alternations made in microstructure of cheese and as a result its density during ripening that lead to decrease of surface regions that distribute light. Perhaps protein's hydration and as a result free water drops decline; also can decrease light distribution and cheese whiteness. Generally when unextractable serum amount is high and casein concentration, soluble in serum phase, goes up, L–Value of cheese declines [29-31].

**Sensory Evaluation:** Table 7 shows results of sensory evaluation. We observed whatever we expected. Full fat cheese had the highest privileges in any terms. Fat content decline had strong effects on texture, taste and general acceptance of Iranian white cheese. RFC had the least privileges in any terms. Among cheese treated with Arabic gum, A2 had the highest privileges in terms of appearance. In terms of texture; also, A2 and in general acceptance view A1 had the most privileges. Softness and good whiteness let A2 to have highest privileges in appearance and texture view.

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**Abbreviation:**

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

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

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

SN : Soluble nitrogen, NPN=Non protein nitrogen,
TN : Total nitrogen,
FFC : Full fat control cheese produced with complete milk that containing 3.2% fat without gum,
RFC : Reduced fat control cheese that was made up of skim milk, having 0.4% of fat with out adding any gum,
A1 : Reduced fat cheese with 0.2 gram Arabic gum per each kilogram of producing milk (skim milk with 0.04% fat),
A2 : Reduced fat cheese with 0.5 gram Arabic gum per kilogram of producing milk (skim milk with 0.04% fat),
A3 : Reduced fat cheese with 0.75 gram Arabic 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