Research article

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Physicochemical, rheological, and sensory properties of low-fat Mozzarella cheese formulated with tragacanth gum

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Abstract

Background and objective: Excessive intake of fatty foods is a risk factor in development of cardiovascular diseases. Use of fat substitutes in formulation of foods could decrease burden of the associated diseases. This work aimed to study the effect of tragacanth gum as a fat substitute on rheological, physicochemical, and sensory attributes of Mozzarella cheese.

Materials and methods: Tragacanth gum at concentration of 0.5, 1, 1.5, and 2% w/w and milk fat at concentration of 12, 14, 16, 18, and 20% w/w were used for cheese making. Sensory test was done by 5-point hedonic method. Rheological analysis was included to determination of storage modulus (G'), loss modulus (G''), cohesiveness, adhesiveness, elasticity, and tensility. Physicochemical characteristics were studied by determination of pH, fat, protein, moisture, dry matter, and melting point. All experiments were performed on days 1, 15, and 30 of storage on the samples stored at 4 °C.

Results and conclusion: By storing the treatments at 4°C, pH, moisture, cohesiveness, elasticity, and tensility decreased, while dry matter, melting point, fat, protein, and adhesiveness increased. Lower amounts of fat, dry matter, and protein were determined in the samples containing higher tragacanth gum. In comparison, moisture, melting point, cohesiveness, elasticity, adhesiveness, and tensility were increased in the samples formulated with higher gum. Viscoelastic behavior of the treatments was time-dependent, so that a linear behavior was observed up to 1000 sec for all treatments, followed by their logarithmic increase. Sensory evaluators preferred the sample containing 18% w/w milk fat and 0.5% w/w tragacanth gum. With respect to the nutritionists' recommendation about consumption of low-fat dairies, the preferred Mozzarella cheese by its desired organoleptic and technical characteristics would be an appropriate choice for those seeking for healthy food basket.

Keywords: Fat substitute, Mozzarella cheese, organoleptic attributes, rheology, tragacanth gum

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1. Introduction

Cardiovascular diseases are the leading cause of death in the world. Today, people pay more attention to their health and quality of nutrition. Importantly, they are aware of health consequences of high fat diet. Indeed, consumption of fatty foods is directly associated with obesity, as a risk factor of cardiovascular diseases [1]. In this regard, fat substitutes are interested in development of novel low-fat foods with same taste and texture as the common products [2].

One of main challenges in formulation of low-fat cheese is a high protein to fat ratio that leads to a compact structure, firm and rubbery texture, loss of flavor, bitterness, undesired melting properties, and a translucent appearance [3-5]. To solve these technical issues, the moisture content is adjusted by addition of materials with high water holding capacity (e.g., hydrocolloids) to cheese [5]. Accordingly, several carbohydrate-based fat substitutes such as Stellar™, Novagel™, microcrystalline cellulose, carrageenan, Arabic gum, polyanionic gum, starch, β-glucan, and tragacanth gum have been used for production of various cheeses [3,5].

Tragacanth is gummy exudate of *Astragalus leguminosae* grown in Southwest Asia, especially Iran and Turkey. It consists of water-insoluble fraction (known as bassorin; 60-70%) and water-soluble fraction (known as tragacanthin; 30-40 %). Tragacanth has been generally recognized as safe by the US Food and Drug Administration and is used in various foods as stabilizer, viscosity enhancer, emulsifier, and thickener [6-8].

Mozzarella, Provolone, Casiukawalu, Romano, and Grana are of common cheeses used in Bati Palia (Italy). Mozzarella cheese belongs to the pastafilata family of soft cheeses and contains 18-24% w/w fat. There are different types of Mozzarella cheese based on their components (cow or buffalo milk, fat level, moisture content, etc.), method of production (biological and chemical), consumption pattern (direct consumption as food or for preparation of other foods), type of packaging, and texture [9]. According to the Codex Alimentarius, low-fat cheese should have 10-25% fat in dry matter. Moreover, up 30% w/w fat per serving (i.e., per 50 g of the product) was defined for low-fat Mozzarella cheese by the US FDA [10].

Several studies have examined the use of hydrocolloids in development of novel functional foods. They include the use of tragacanth as fat substitute in ice cream and cheddar cheese [11-13], konjac glucomannan as fat replacer in Mozzarella cheese [14], and inulin as fat replacer and plasticizer in low-fat Mozzarella cheese [15]. Considering the desired technical and organoleptic results presented in other studies with respect to the use of tragacanth gum as fat substitute, we studied it in development of low-fat Mozzarella cheese. In this work, physicochemical, rheological, and sensory properties of the products were studied.

2. Materials and methods

2.1. Materials

Thermophilic starter cultures of *Lactobacillus helveticus* and *Streptococcus thermophilus* were purchased from Christian Hansen Company (Denmark). Cow milk (Pardis Iran livestock), cheese (Meito Company, Japan), citric acid, calcium chloride, and salt (Merck, Germany), potassium sulfate, copper sulfate, methyl red, green bromocrosol, boric acid, sucrose, normal hydrochloric acid 0.1N, sulfuric acid 90%, isoamyl alcohol, phenylphthalin, ammonia sulfate, sodium hydroxide 0.1N, and potassium permanganate (Neutron, Iran), and tragacanth gum (Reihan Gam Parsian Company, Iran) were of the raw materials used in the current work.

2.2. Mozzarella cheese preparation

At first, cow milk was pasteurized at 72 °C for 15 min. After cooling, citric acid was added to adjust pH to 5.8 (pre-acidification) followed by rennet addition. Then, the starters of *L. helveticus* and *S. thermophilus* and calcium chloride were added to form gel. In the next step, the gel was cut and stored until pH dropped to 5.2. The acidified gels were cooked in hot water at temperature of 80 °C to form a pasty texture. Then, it was cut into pieces and put in flowing water at 10-12 °C. Finally, the sample was placed in saline solution at 5 °C for 30 min and stored at 4 °C until analysis [9].

2.3. Treatments

Our samples were included to T_1 containing 20% milk fat without tragacanth (control), T_2 containing 18% milk fat with 0.5% w/w tragacanth, T_3 containing 16% milk fat with 1% w/w tragacanth, T_4 containing 14% milk fat with 1.5% w/w tragacanth, and T_5 containing 12% milk fat with 2% w/w tragacanth.

2.4. Physicochemical tests

These were included to determination of pH, fat, protein, moisture, dry matter, and melting point according to guidelines provided by the Institute of Standards and Industrial Research of Iran [16-21].

2.5. Rheological analysis

The texture was analyzed by Lloyd instrument (Ametek Company, UK). Tensility, elasticity, cohesiveness, adhesiveness, storage modulus (G'), and loss modulus (G") were studied according to Iranian guidelines [21,22]. The samples were in cylindrical shape with diameter of 22.2 mm and height of 18 mm. They were compressed in two cycles at 60 mm/min up to 25% of their original height. Shear rate of 0.83 mm/s was used for analysis. Diameter of the probe was 50 mm. Analysis was done at room temperature (25 ºC) [23].

2.6. Sensory evaluation

Seven trained evaluators examined the samples by 5-point hedonic method. They evaluated color, odor, flavor, texture, and overall acceptance. The scales were included to 1 = extremely dislike, 2 = dislike, 3 = neither like nor dislike, 4 = like, and 5 = extremely like [7].

2.7. Statistical analysis

The data were analyzed by SPSS software version 21. Analysis of variances (ANOVA) was used to compare the means followed by Duncan test to find the significant differences. The experiments were done in triplicate and data are presented as mean ±standard deviation. Differences were significant at $p \leq 0.05$. The graphs were designed by Excel software.

3. Results and discussion

3.1. Physicochemical properties

3.1.1. pH

Changes of pH in Mozzarella cheese is linked to microbial growth and protein/peptide proteolysis. The starter bacteria ferment lactose during ripening and produce lactic acid, which leads to pH drop. In parallel, proteolysis is occurred by the activity of microbial enzymes [24,25]. Milk contains β-galactosidase, phospho-β-galactosidase, and extracellular proteases and lipases that utilize lactose, casein, whey proteins, and milk fat. The enzymes are also active after bacterial death [26]. Our results are in line with these findings so that the lowest pH was observed on day 30 for all treatments (Figure 1).

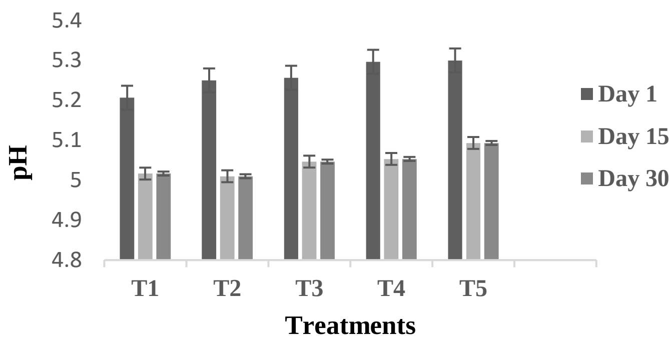

Figure 1- Changes of pH in the samples during 30 days of storage; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

Addition of hydrocolloids to dairy products may have protective effect on the starter bacteria providing more acid production and pH drop. Although, the samples with higher concentration of tragacanth had lower acidity and higher pH (Figure 1). Our findings are also different from the results reported by Gulzar et al. about physicochemical changes of Mozzarella cheese produced from buffalo milk [27]. Fermentation rate and acid production is significantly affected by concentration of hydrocolloids. The opposite result of our study might be due to the viscosifying role of tragacanth gum especially at high concentrations by limiting the availability of substrates to the hydrolyzing enzymes responsible for organic acid production. As seen in the figure, differences are not significant at lower concentrations.

3.1.2. Fat concentration

The highest and the lowest fat was observed in T_1 on day 30 (30.48%) and T_5 on day 1 (29.37%), respectively (Figure 2). The samples formulated with tragacanth gum had less fat in dry matter ($p < 0.05$), possibly due to the absorption of water by tragacanth [3,28]. Interestingly, fat concentration of each sample increased during storage as a result of water holding capacity of the gum. Similar result was reported by Mirzaei and Aligholi Nejad for Lighvan cheese during 90 days of storage [24]. In comparison, Shahab Lavasani et al. reported that fat concentration of Lighvan cheese decreased during ripening, which was due to lipolysis and further release of fatty acids from cheese to water [29].

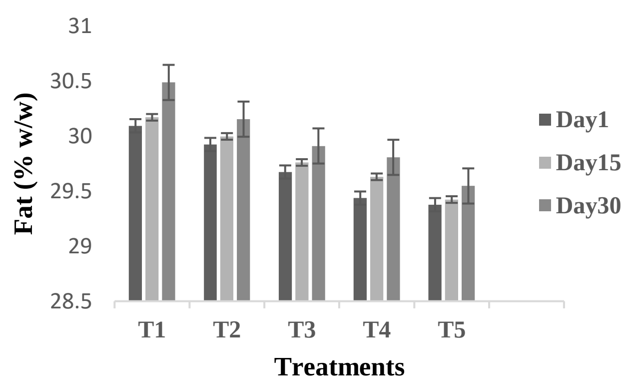

Figure 2- Fat concentration of the samples during 30 days of storage; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

3.1.3. Protein concentration

Protein had no significant change in the samples during storage. However, it decreased significantly by increasing the gum concentration in Mozzarella cheese. The highest and the lowest protein was observed in T_1 on day 30 (25.91%) and T_5 on day 1 (24.82%), respectively (Figure 3).

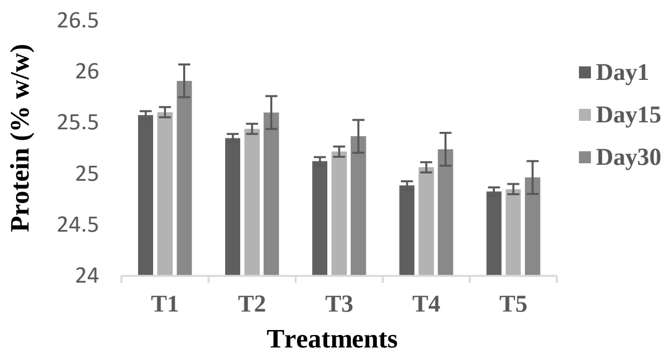

Figure 3- Protein concentration of the samples during 30 days of storage; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

During ripening, proteolysis is responsible for taste development by releasing peptides, amino acids, and aromatic compounds into the sample. However, quantity of proteinaceous components does not change based on the law of conservation of mass. Indeed, long chain peptides engage in texture development and short chain peptides contribute to taste development [27].

3.1.4. Moisture

Amount of moisture in the curd depends on method of processing. The gel network may contain 87% initial moisture, which gradually reduced to 20-56% during storage [30]. As demonstrated in Figure 4, the highest moisture content was observed in T_5 on day 1 (57.13%) and the lowest amount of moisture was found in T_1 on day 30 (56.29%). In cheese making, formation of three-dimensional gel developed by casein micelles leads to entrapment of water molecules in the curd. However, hydrocolloids have high water holding capacity and keep more water in the protein structure when added to the formula [31,32]. On the other hand, moisture loss and undesirable texture is of technical challenges in formulation of low-fat cheese. Hygroscopic fat replacers such as tragacanth gum avoid syneresis and provide a similar texture to the common products [33-36].

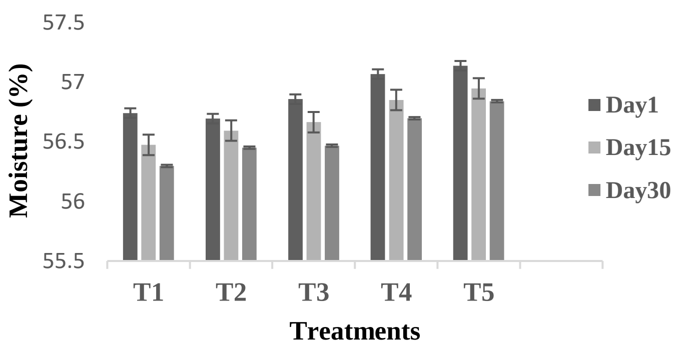

Figure 4- Moisture content of the samples during 30 days of storage; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

3.1.5. Dry matter

During 30 days of storage at 4 °C, dry matter of the samples increased which might be due to water evaporation. Moreover, there was significant difference between the treatments so that dry matter decreased significantly by increasing the gum concentration (Figure 5). As mentioned above, tragacanth absorbs water molecules and retains moisture within the structure, resulting in lower dry matter in the product [27,37]. In fact, the negatively charged tragacanth gum interacts with the positively charged casein and provides space between casein micelles through which hydrophobic bonds are reduced [13,34,38]. According to the results, the highest and the lowest dry matter was observed in T_1 on day 30 (43.70 %) and T_5 on day 1 (42.86%), respectively. Our results were in agreement with those reported by Cooke et al. in formulation of low-fat cheddar cheese [13] and Rahimi et al. in formulation of low-fat white cheese [39] by tragacanth gum as fat substitute.

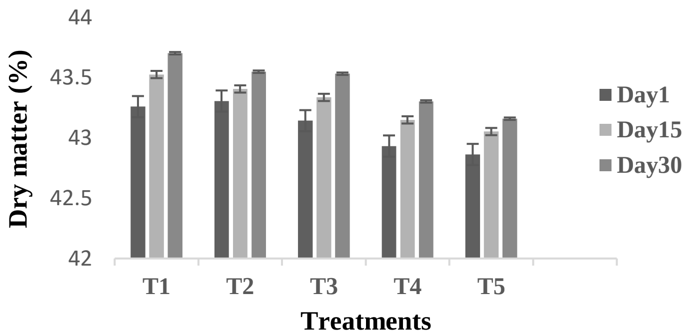

Figure 5- Dry matter of the samples during 30 days of storage; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

3.1.6. Melting point

As depicted in Figure 6, melting point increased in the samples by increasing the concentration of tragacanth gum in the formula. The highest melting point was related to T_5 on day 30 (232.47 ºC) and the lowest melting point was recorded for T_2 on day 1 (172.86 ºC). The increased melting point followed by addition of tragacanth gum to the samples was possibly due to its role as viscosifying agent and the changes in glass transition temperature [40]. Cais-Sokolinska et al. studied melting point of fried ripened curd cheese during 28 days of storage. They found that meltability of the samples decreased during storage by reduction of fat concentration [41].

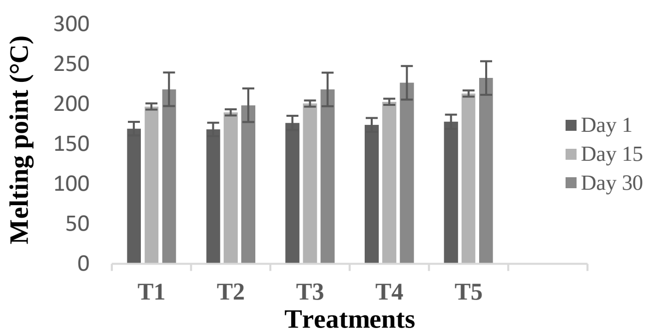

Figure 6- Melting point of the samples during 30 days of storage; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

3.2. Rheological characteristics

Cohesiveness is defined as the required force to compress a material before its rupture, that is directed by the chemical bonds in the structure [42]. Our analysis revealed that the reduced-fat sample containing 2% w/w tragacanth (T_5) on day 30 had the lowest cohesiveness (0.38) and the control (T_1; tragacanth-free sample) on day 1 had the highest cohesiveness (0.83) (Table 1). It significantly shows the role of tragacanth gum in retention of the texture [43,44]. Similar results were reported by Cooke et al. for low-fat cheddar cheese formulated with tragacanth [13] and Koca and Metin for low-fat Kashar cheese formulated with other fat replacers [37]. As seen in the table, between-group differences are significant when concentration of gum increases.

Table 1- Cohesiveness of the Mozzarella cheese samples during 30 days of storage

	Cohesiveness				
Day	T_1	T_2	T_3	T_4	T_5
1	0.83 ±0.01^{aA}	0.81 ±0.01^{aA}	0.73 ±0.01^{aB}	0.76 ±0.01^{aC}	0.69 ±0.01^{aD}
15	0.58 ±0.01^{bA}	0.60 ±0.01^{bA}	0.53 ±0.01^{bB}	0.50 ±0.01^{bC}	0.49 ±0.01^{bC}
30	0.42 ±0.01^{cAB}	0.44 ±0.01^{cA}	0.40 ±0.01^{cB}	0.41 ±0.01^{cB}	0.38 ±0.01^{cC}

*Small letters show significant differences in the columns ($p \leq 0.05$).
**Capital letters show significant differences in the rows ($p \leq 0.05$).
T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

The highest elasticity (31.98 J/m^3) was related to T_5 on day 1, and the lowest elasticity (14.30 J/m^3) was observed in T_1 on day 30 (Table 2). Elastic texture of cheese is rapidly changed to smooth and uniform texture as a result of two-phase proteolysis. Milk caseins are initially broken down to high molecular weight peptides by renin and plasmin (both are present in cheese). Indeed, rennet-induced proteinase is primarily responsible for initial proteolysis of caseins during ripening. In the second phase, these enzymes produce other compounds by breaking down of α_{s1}-casein- and β-casein, which are responsible for cheese texture development [45].

Table 2- Elasticity of the Mozzarella cheese samples during 30 days of storage

	Elasticity (J/m^3)				
Day	T_1	T_2	T_3	T_4	T_5
1	26.63 ±0.10^{aC}	28.59 ±0.1^{aB}	28.75 ±0.13^{aB}	31.96 ±0.03^{aA}	31.98 ±0.09^{aA}
15	18.56 ±0.09^{bC}	19.54 ±0.18^{bB}	19.68 ±0.14^{bB}	22.61 ±0.04^{bA}	22.45 ±0.12^{bA}
30	14.30 ±0.06^{cE}	15.96 ±0.19^{cD}	14.63 ±0.17^{cC}	17.04 ±0.03^{cB}	16.22 ±0.11^{cA}

*Small letters show significant differences in the columns ($p \leq 0.05$).
**Capital letters show significant differences in the rows ($p \leq 0.05$).
T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

Adhesiveness is defined as the required force to overcome the attractive forces between the food and probe surface [42]. Addition of tragacanth gum especially at higher concentrations to the Mozzarella cheese significantly affected this feature. According to Table 3, the highest and the lowest adhesiveness was respectively observed in T_5 on day 30 (0.40 J/m^2) and T_1 on day 1 (0.11 J/m^2). In this regard, the role of tragacanth gum as a carbohydrate-based fat substitute and its interaction with water molecules is of interest [44].

Table 3- Adhesiveness of the Mozzarella cheese samples during 30 days of storage

	Adhesiveness (J/m^2)				
Day	T_1	T_2	T_3	T_4	T_5
1	0.11 ±0.01^{cD}	0.19 ±0.01^{cC}	0.13 ±0.01^{cBD}	0.15 ±0.01^{cB}	0.24 ±0.01^{bA}
15	0.16 ±0.01^{bE}	0.30 ±0.01^{bD}	0.21 ±0.01^{bC}	0.25 ±0.01^{bB}	0.39 ±0.01^{aA}
30	0.23 ±0.01^{aE}	0.34 ±0.01^{aD}	0.25 ±0.01^{aCE}	0.30 ±0.01^{aB}	0.40 ±0.01^{aA}

*Small letters show significant differences in the columns ($p \leq 0.05$).
**Capital letters show significant differences in the rows ($p \leq 0.05$).
T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

The highest tensility was recorded for T_5 on day 1 (35.77 cm), while the lowest amount was observed in T_1 on day 30 (4.69 cm). In addition, tensility of the samples decreased significantly with increasing the storage time (Table 4). Effect of xanthan gum and sodium caseinate as fat substitute on textural properties of low-fat Mozzarella cheese was investigated by Nateghi and Moradi Moghadam [34]. In their study, the authors observed increased cohesiveness and decreased tensility in the low-fat samples, that might be due to a different behavior of xanthan gum in the matrix. Accordingly, xanthan gum increased the yield of process along with development of acceptable texture.

Table 4- Tensility of the Mozzarella cheese samples during 30 days of storage

	Tensility (cm)				
Day	T_1	T_2	T_3	T_4	T_5
1	16.79 ±0.67^{aE}	25.17 ±0.80^{aD}	28.78 ±0.61^{aC}	33.35 ±1.43^{aB}	35.77 ±0.47^{aA}
15	9.84 ±1.11^{bE}	16.27 ±0.24^{bD}	19.45 ±1.15^{bC}	22.75 ±0.69^{bB}	26.12 ±0.72^{bA}
30	4.69 ±0.85^{cE}	12.48 ±0.54^{cD}	15.03 ±0.44^{cC}	16.66 ±1.03^{cB}	19.22 ±0.50^{cA}

*Small letters show significant differences in the columns ($p \leq 0.05$).
**Capital letters show significant differences in the rows ($p \leq 0.05$).
T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

Hydrocolloids and ionic materials affect fermentation rate and can improve the taste and the texture of cheese during storage. Therefore, rheological characteristics of the product are affected by changing their concentration [46]. Khosroshahi et al. investigated rheological properties of Iranian white cheese at various temperatures. In their study, higher viscoelastic behavior was observed in the samples containing lower fat and higher protein [47]. Similar results were reported in study of Tidona et al. in formulation of Mozzarella cheese with skim milk [48].

In our study, viscoelastic behavior of the Mozzarella cheese samples was time dependent, so that a linear trend was observed up to 1000 sec in all treatments. It means that the samples had appropriate stability under the applied shear rate of 0.83 mm/s at 25 ºC. Although, storage modulus (G') was less than loss modulus (G") all the time and their difference was more significant after 1000 sec. It shows that viscous behavior of the samples was superior to their elastic behavior (Figures 7, 8, 9).

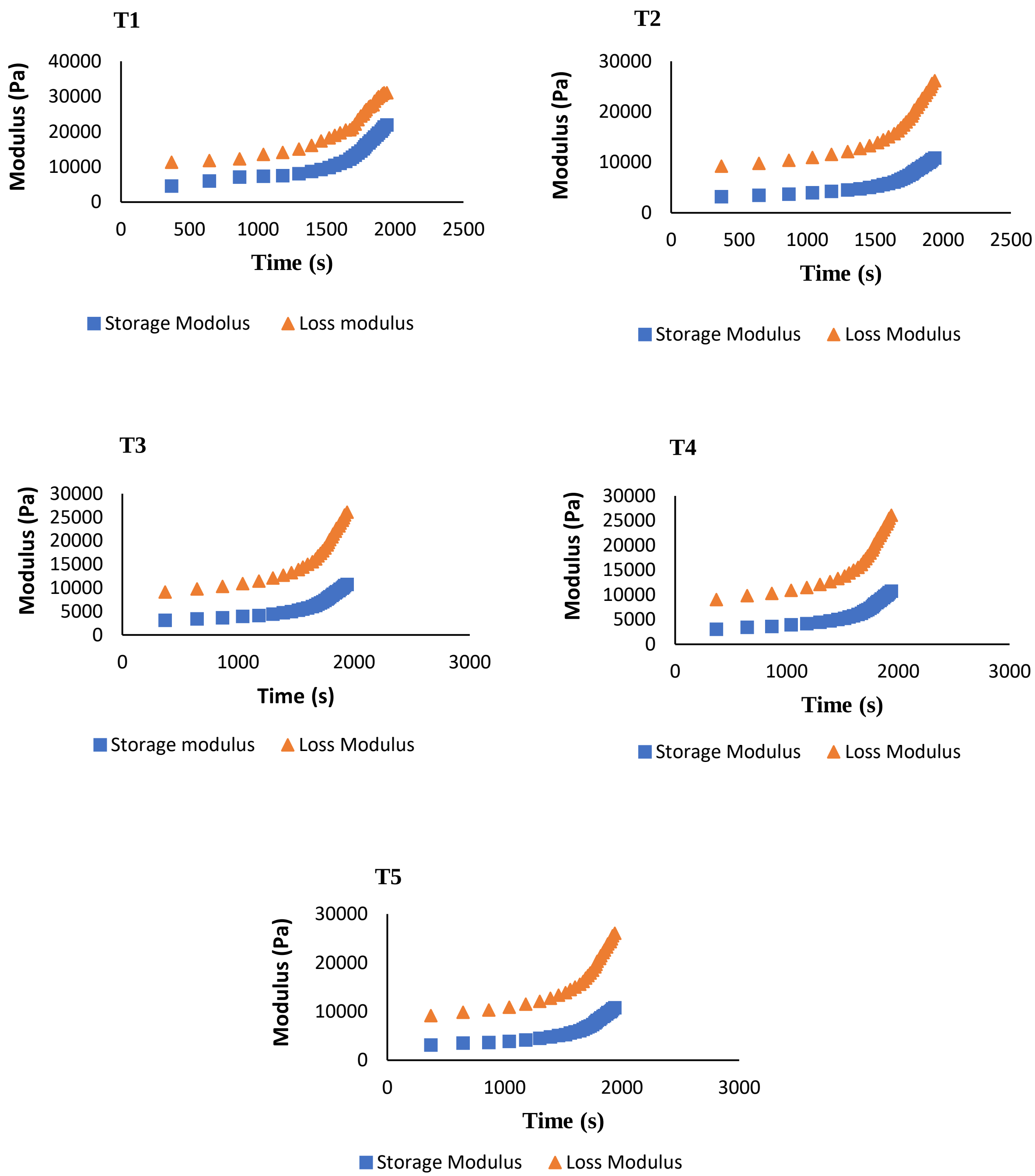

Figure 7- Storage modulus (G') and loss modulus (G") of the Mozzarella cheese samples on day 1; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

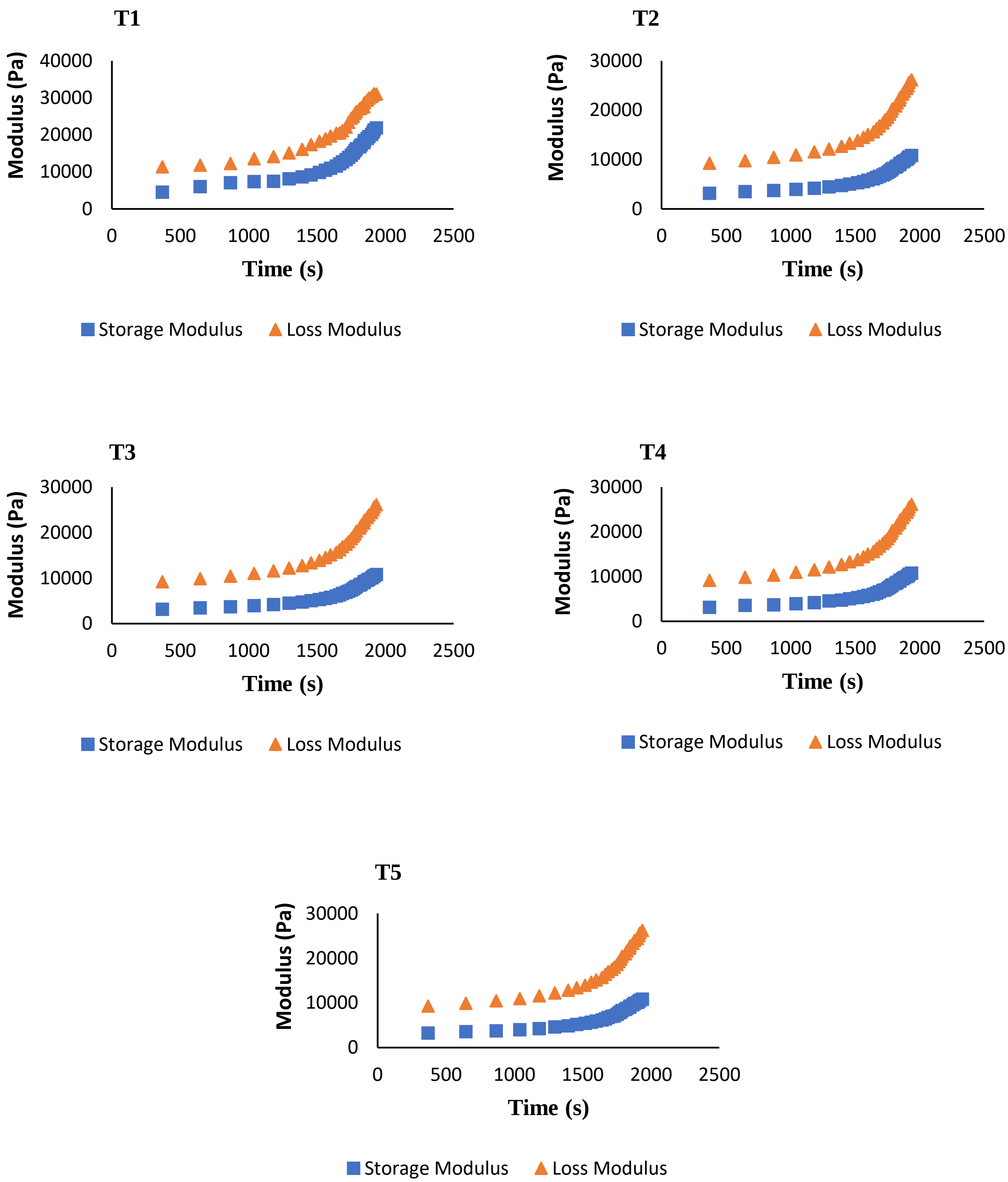

Figure 8- Storage modulus (G') and loss modulus (G") of the Mozzarella cheese samples on day 15; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

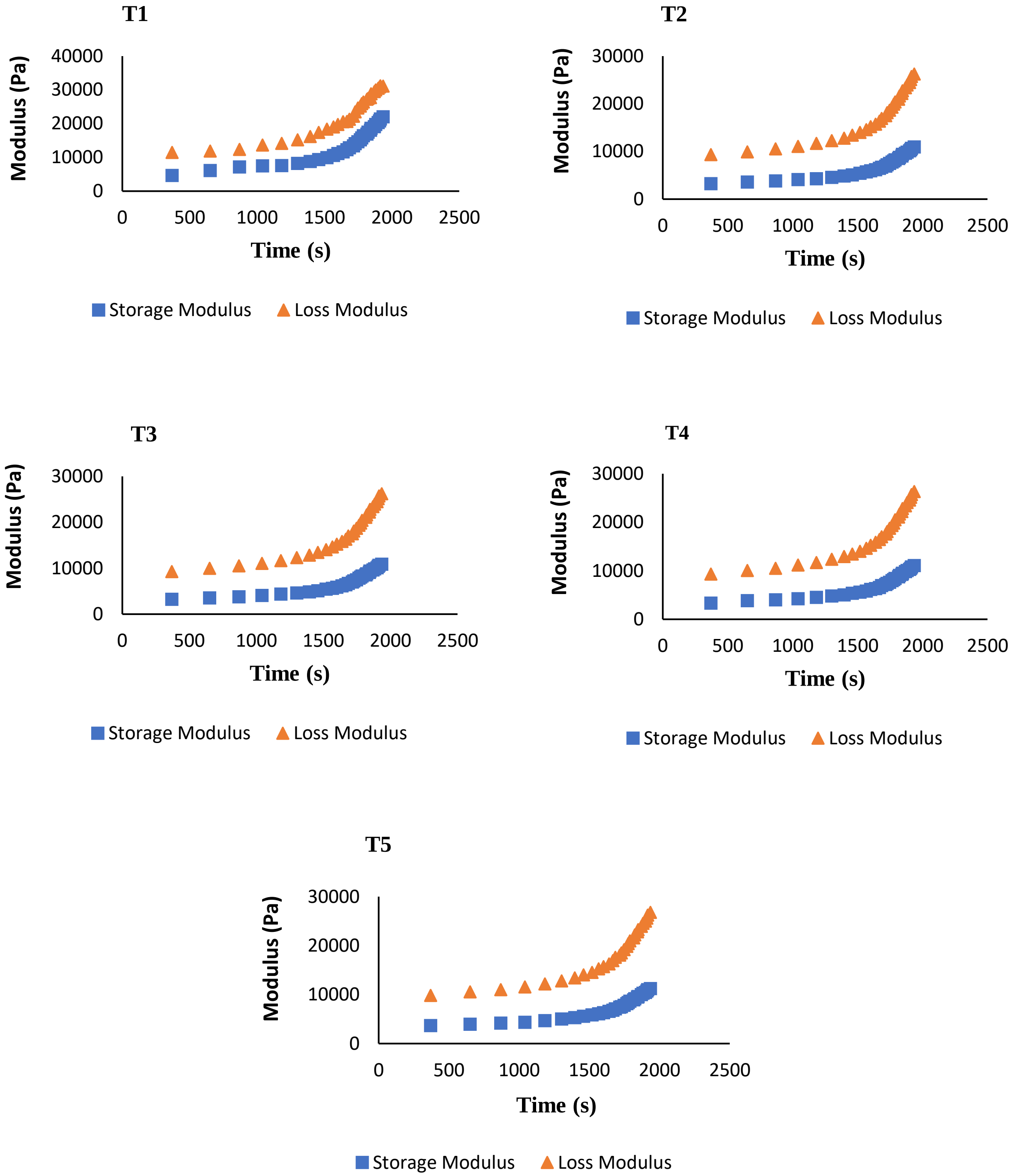

Figure 9- Storage modulus (G') and loss modulus (G") of the Mozzarella cheese samples on day 30; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

3.3. Sensory attributes

As illustrated in Figure 10, acceptability of the treatments decreased by increasing the concentration of tragacanth. As seen, T_2 (containing 0.5% w/w gum) and T_1 (control; gum-free sample) were preferred by the evaluators. However, the overall acceptance did change significantly over time.

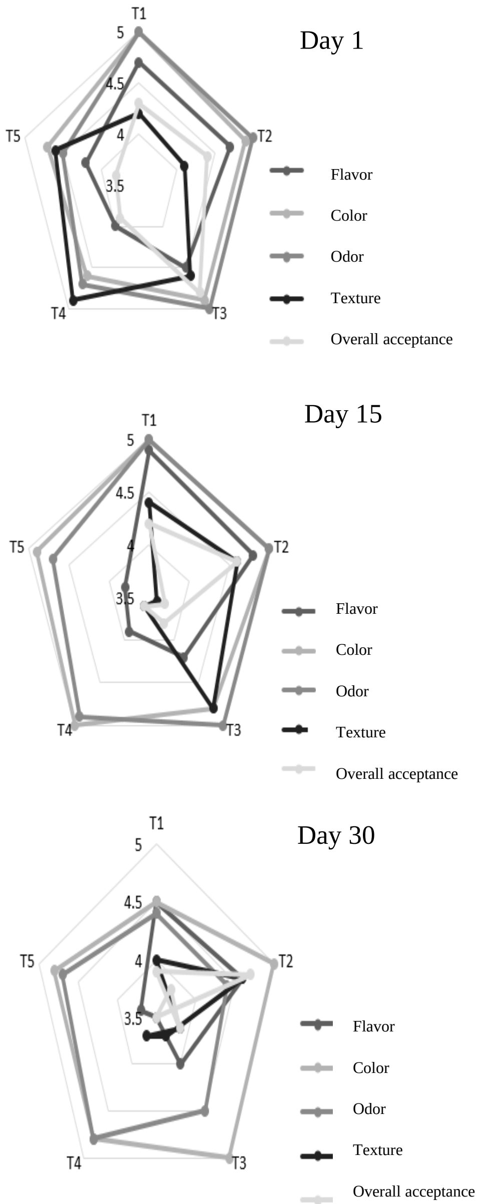

Figure 10- Sensory evaluation of the Mozzarella cheese samples during 30 days of storage; T_1 contains 20% milk fat without tragacanth (control), T_2 contains 18% milk fat with 0.5% w/w tragacanth, T_3 contains 16% milk fat with 1% w/w tragacanth, T_4 contains 14% milk fat with 1.5% w/w tragacanth, and T_5 contains 12% milk fat with 2% w/w tragacanth

Fat content, rate of cheese ripening, proteolysis and lipolysis level, and intensity of milk homogenization affect the sensory attributes of Mozzarella cheese. Interestingly, no significant difference in organoleptic properties is observed between the treatments on the first day of production due to the low metabolites produced by the starter bacteria responsible for synthesis of flavor peptides [49]. During ripening, lipolysis produces glycerol and free fatty acids (particularly short chain fatty acids), followed by development of tasty compounds such as methyl ketones, secondary alcohols, esters, and lactones [50,51]. Therefore, it is clear that reduction of fat content in the formula negatively affects the flavor.

4. Conclusion

Addition of tragacanth gum to Mozzarella cheese as a fat substitute changed the physicochemical and the rheological properties of the samples. It was greatly affected by the high water holding capacity of tragacanth, which could reduce syneresis and dry matter of the products. Furthermore, tragacanth is a negatively charged carbohydrate-based hydrocolloid able to interact with the positivity charged proteins in the matrix, through which viscoelastic behavior of the formula is affected. Although, viscous behavior of our samples was dominant compared to their elastic behavior. By increasing the gum concentration more than 0.5 w/w, acceptability of the samples decreased. It was due to the fact that fat lipolysis has significant impact on sensory attributes of cheese during ripening by production of free fatty acids responsible for taste development. However, T_2 (containing 0.5% w/w tragacanth and 18% w/w fat) was accepted by the sensory evaluators. Therefore, it can be used in formulation of low-fat Mozzarella cheese.

5. Conflict of interest

The authors declare that they have no conflict of interests.

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