Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Impact of addition of Persian gum and microbial transglutaminase enzyme on the textural characteristics of semi-fat ultrafiltrated white cheese

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ARTICLE INFO

Article History:
Received:2024/3/26
Accepted:2024/5/8

Keywords:

Enzymatic treatment,
Fat replacer,
Syneresis,
Texture profile analysis

DOI: 10.22034/FSCT.21.156.110.

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ABSTRACT

The current investigation was conducted to study the effect of Persian gum (PG) and microbial transglutaminase (MTGase) on textural characteristics of ultrafiltrated semi-fat white cheese during 60 days of cold storage. In order to produce semi-fat cheeses, PG was used at three levels of 0, 0.25, and 0.5% and MTGase enzyme at three levels of 0, 0.5 and 1 unit (U) per gram of protein. Cheese samples without any treatment were considered as control samples. The findings of this study revealed that addition of PG, opposite to MTGase, caused a significant reduction of the cheese pH values ($p < 0.05$). During the storage period, the pH values of all cheese samples decreased, but statistically there was a significant difference only between the first and 30th days of storage. During the storage period, the addition of PG led to a decrease in the amount of hydration of the samples until the 30th day of storage, but then the amount of hydration of the samples increased until the end of the 60th day. The results obtained from the analysis of the texture characteristics revealed that MTGase treatment up to 0.5 U decreased the firmness, gumminess, springiness and chewability and increased the adhesiveness of the cheese samples, but using a higher amount of the enzyme (1 U) caused a significant contrary change in the mentioned trend ($p>0.001$). Also, the addition of PG decreased the firmness, cohesiveness, gumminess, springiness and chewability and increased the adhesiveness of the cheese samples ($p < 0.001$). In general, with the passage of time during the cold storage, all the textural parameters, except adhesiveness, decreased significantly. The results of this research showed that it is possible to produce cheese with good quality by using the levels of 0.25 to 0.5% PG and 0.5 unit of MTGase.

[DOI: 10.22034/FSCT.21.156.110]

1- Introduction

Nowadays, due to the increase in people's awareness of healthy food consumption, the demand for the production of low-fat cheeses has increased dramatically. In recent years, the production of low-fat cheeses with qualitative characteristics similar to high-fat cheeses has attracted the attention of many researchers around the world. On the other hand, reducing the amount of fat causes extensive changes in the texture, melting characteristics, as well as the organoleptic characteristics of these dairy products [1]. The use of fat substitutes is one of the most effective solutions to overcome the problems caused by reducing the fat of cheeses, adding them improves the quality of food, reduces the amount of fat, and also reduces calorie intake. Excessive stiffness of the texture, reduction of aroma and taste and unfavorable melting characteristics are the main problems in the formulation of low-fat cheese. In order to solve these problems, by adding compounds with high water holding capacity such as hydrocolloids to cheese, the moisture level of this product can be adjusted [2].

Many studies have shown that plant polysaccharides have various biological properties such as antioxidant properties, inhibition of free radicals, immunity stimulation and antiviral properties [3]. Gums are one of the most widely used polysaccharides, which are used as fat substitutes in a variety of food products, including dairy industry. Persian gum (PG) is an anionic gum extracted from the trunk and branches of the wild almond tree (scientific name: *Amygdalus scoparia*), which often grows in the central regions of Iran. Having features such as high water absorption, low cost, and availability have made Persian gum a potential alternative to common gums in the food industry. This gum can have potential applications such as thickener, emulsifier, suspension and stabilizer in various food products [4].

In addition, various enzymes are used in the food industry to improve the technological characteristics, increase the nutritional value and the production efficiency of various products. Microbial transglutaminase (MTGase, protein-glutamine-ε-glutamyltransferase, EC 2.3.2.13) is one of the most widely used enzymes in the dairy industry, especially the cheese industry. Transglutaminase belongs to the family of transferases, which catalyzes cross-links between the γ-carboxyamide groups of glutamine residues and the ε-amino groups of lysine residues in polypeptide chains which forms ε-(¬γ-glutamyl¬) lysine (G-L). Transglutaminase enzyme plays a role in increasing the yield of cheese production, increasing the water holding capacity, improving the texture, increasing the shelf life, and also improving the textural and sensory characteristics of cheese. In addition, this enzyme has nutritional, economic and environmental importance [2, 5].

The findings of a similar study revealed that compared to the control cheese sample, the samples treated with MTGase and lipase enzyme had higher proteolysis and lipolysis activity during the storage period. In addition, the tissue analysis showed a slight increase in the hardness of the enzyme-treated samples. Treated samples also had higher tissue acceptability [5]. Similarly, the results of the effect of adding MTGase on the quality characteristics of soft cheeses made from camel milk showed that the cheeses treated with the enzyme had a significantly higher cheese-making yield compared to the control sample. The actual yield of all cheeses treated with MTGase varied from 19% to 20.5%. In addition, it was found that the samples treated with 80 U of the enzyme have the highest level of hardness. By increasing the concentration of MTGase higher than 80 U, a significant decrease in the hardness of the samples was observed. However, there was no significant difference between the hardness of samples containing U 100 and 120 from MTGase [4].

In another study, the effect of Persian and almond gums as fat substitutes on the physicochemical, rheological and microstructural characteristics of Iranian low-fat white cheeses

[DOI: 10.22034/FSCT.21.156.110]

was investigated. The used gums effectively increased the ratio of moisture to protein (M:P) of the low-fat cheese samples, which significantly reduced the parameters of hardness, breaking stress, Young's modulus and storage modulus (G'), but the effect of Persian gum was more obvious. In addition, the addition of gum increased the yield of cheese production and also increased the rate of proteolysis. The optimization of production conditions showed that the use of cheese-making milk containing 0.9% fat, 0.2% Persian gum and 0.12% almond gum leads to the production of low-fat cheese with textural characteristics similar to its high-fat varieties [6]. According to the mentioned cases, the present study was conducted with the aim of investigating the effect of Persian gum and microbial transglutaminase enzyme on some physicochemical and textural characteristics of ultrafiltrated low-fat white cheese.

2- Materials and methods

2-1- Raw materials

Ultrafiltrated (UF) cheese samples were made using produced retentate at Pegah factory in Khuzestan, located at the 3rd kilometer of Shush-Dezful road. Milk protein concentrate powder (MPC) was obtained from Pegah Khorasan Company. Persian gum (PG) was obtained from a local shop in Mollasani, and after cleaning and washing, gum powder was prepared. Rennilase culture was purchased from Christian Hansen (Copenhagen, Denmark). Microbial transglutaminase (MTGase) enzyme powder with an average activity of 100 units per gram of protein was obtained from BDF Natural Ingredients (Girona, Spain).

2-2- Production of low-fat cheese samples using ultra-filtrated method

The processed cheese samples were produced in Pegah dairy factory in Khuzestan. In order to produce cheese, high quality fresh cow's milk was used. After the milk was received by the factory, its temperature was reduced to about 5 °C by a plate heat exchanger and then it was stored in steel tanks until the process was carried out. The milk was directed from the storage tanks to the pasteurization line and then its temperature was increased to 50 °C. After transferring the milk to the creamer and adjusting its fat content to 3%, the milk was passed through two bactofugation devices to reduce its microbial load to more than 99%. In the next stage, the milk was pasteurized at a temperature of 72°C for 15 seconds, and after cooling it with a plate heat exchanger to a temperature of about 5°C, the pasteurized milk was stored in tanks. In order to produce ultrafiltrated cheese, first pasteurized milk was sent to the cheese production line and its temperature was increased to 50 °C by a heat exchanger. Then, to concentrate the milk, it was transferred to the ultrafiltration (UF) system. After passing through the UF system, the amount of milk dry matter was about 32%.

In the next stage, milk protein concentrate powder (MPC) with the same dry matter as retentate (32%) was added to retentate in an equal amount (volume/volume) to reduce the amount of fat by half. After adding Persian gum at three levels of 0%, 0.25% and 0.5% (volume/volume), the mixture was homogenized using a homogenizer (Ronghemamachinery, JHG-Q60-P60, China) and at a temperature of 75 °C was heated for 15 seconds. After cooling retentate to a temperature of about 30 °C, MTGase enzyme was added at the levels of 0, 0.5 and 1 unit (per gram of retentate protein). Then, retentate was filled in 100 cc containers with cheese and 3% of the starter culture mixture and cheese rennet was added to the prepared retentate mixture. Next, the containers were entered into the coagulant tunnel with a temperature of about 30 °C, and after leaving the tunnel, fat-resistant paper was placed on the surface of the cheese samples and 2% (w/w) Salt was added to it. After sealing the cheese containers with aluminum foil, finally, the cheese containers were transferred to a warm room for incubation at a temperature of 35-37 °C, so that after 18-24 hours the pH dropped to about

[DOI: 10.22034/FSCT.21.156.110]

4.8. Finally, the samples were transferred to a cold store with a temperature of 5 °C and physicochemical and texture tests were performed on the cheese [6]. Table 1 shows the characteristics of retentate and MPC compounds used in the production of cheese samples.

Table 1. Chemical properties of retentate and milk protein concentrate (MPC) powder used in the production of cheese samples

Substance	Component (%)			
	Lactose	Ash	Fat	Protein
Retentate	2.70	1.40	15.35	12.38
Milk protein concentrate (MPC)	16.50	8	1.30	70

2-3- pH Measurement

The pH of the cheese samples was measured using a digital pH meter (Metrohm, Model 827, Switzerland) at room temperature [7].

2-4- Syneresis measurement

In order to measure the amount of syneresis, the cheese samples were centrifuged at 1500* g for 15 min at room temperature. Then, the weight of sediment and supernatant was determined using a digital scale. At the end, the percentage of the syneresis of samples was calculated using the following equation [8]:

$$Syneresis\ (\%) = \frac{Amount\ of\ seperated\ whey}{Amount\ of\ cheese\ sample} \times 100$$

2-5-Texture profile analysis (TPA)

Texture profile analysis (TPA) was performed using a texture measuring device (TA.XT.PLUS, Stable Micro System, England) and with probe number P/S5. The speed of the probe was set to 1 s/mm and the probe penetrated up to 50% of the initial height of the cheese samples (10 mm deep) inside the samples. The speed of the probe before and after the test was set to s/mm 2 and 1, respectively. Before the test, the cheese samples were taken out of the refrigerator and kept at room temperature for 30 minutes until a constant temperature was reached. In all the samples, texture testing was done in three different parts of the cheese and the average results were recorded [2]. In this test, the properties of hardness (N), stickiness (N.mm), consistency, elasticity (mm), gummy state (N) and chewability (N.mm) of cheese samples were investigated.

2-6-Statistical analysis

In the present study, three different levels of Persian gum (0, 0.25 and 0.5%, V/V) and microbial transglutaminase enzyme (0, 0.5 and 1 U) were used. All tests were done with three repetitions. Physicochemical and textural characteristics of cheese samples were investigated during the first, thirty and sixtieth days of cold storage. The obtained data were analyzed using SPSS software. In order to investigate the significant difference between cheese treatments, simple analysis of variance was used, and to investigate the mutual effects between treatments and storage time, factorial design was used in a completely random format. The average data were compared at the level of significant difference of 5% ($p < 0.05$). All results were expressed as the mean of three replicates ± standard deviation.

3-Results and Discussion

3-1- pH

As shown in Figure 1, the pH values of the cheese samples were significantly different from each other ($p < 0/05$). In addition, in Table 2, the results

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of variance analysis of different concentrations of MTGase and PG on the pH values of cheese samples during the cold storage period can be seen. In general, the pH values of the samples varied from 4.64 (the sample containing 0 U enzyme and 0.5% gum) to 4.89 (the sample containing 1 U enzyme and 0% gum). During the storage period, the pH values of all cheese samples decreased, but statistically there was a significant difference only between the 1st and 30th days of storage.

In accordance with the findings obtained from this research, in another study, a significant difference was observed between the pH values of quark cheese samples as affected by enzymatic treatment. The sample containing 0.3 L/g of MTGase and 0.06 L/g of lipase enzyme (T3 sample) had the lowest pH value and the control sample (T0, cheese sample without any treatment) had the highest pH value. In addition, during a 21-day storage period, the pH value of most of the samples decreased significantly, and the lowest pH value (about 3.80) for the T3 sample was measured on the 21st day of storage [5]. In a similar research, it was found that the addition of basil seeds, xanthan gum and different concentrations of fat has no significant effect on the pH and acidity of cream cheese [9].

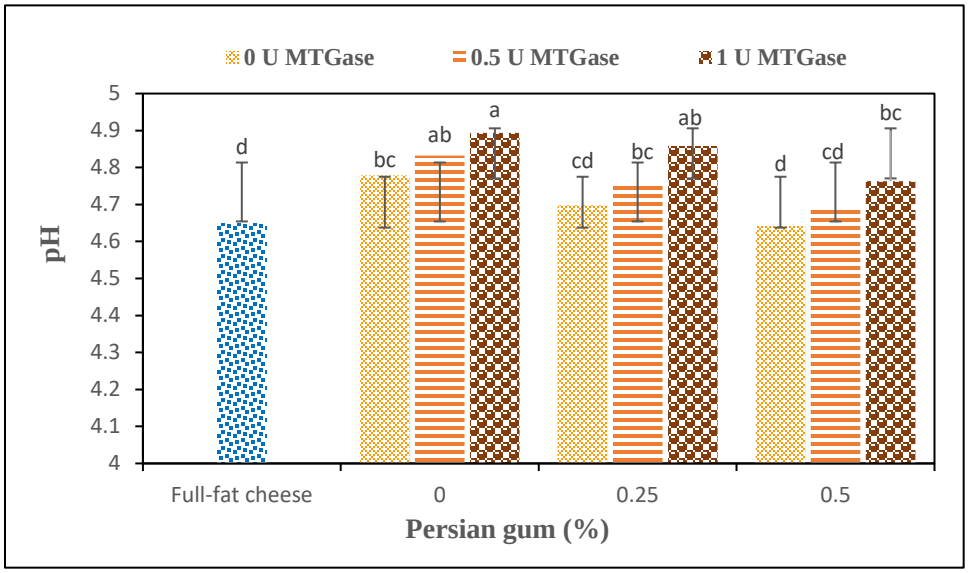

FIG. 1. Effect of different concentration of microbial transglutaminase (MTGase) and Persian gum (PG) on the pH of cheese samples

3-2- Syneresis

The meaning of "syneresis" is the condensation of the protein network as a result of the loss of water from the curd, which can directly affect the quality of the cheese. In other words, during cheese making, syneresis changes the amount of moisture, minerals and lactose in the curd, which affects the ripening of the cheese and consequently the sensory characteristics of the cheese. In general, the main factors influencing the amount of syneresis properties of cheese samples are: pH, cut size, baking temperature, acid formation speed, stirring the mixture of curd and whey, compressing the curd and salting. . Pre-treatment of milk can affect cheese's hydration; For example, high heating of milk (such as long-term pasteurization) causes precipitation of whey proteins, poor coagulation of the rennet, and a decrease in the syneresis content of cheese samples [10].

[DOI: 10.22034/FSCT.21.156.110]

The results of the statistical analysis of the effect of two independent variables of Persian gum enzyme and MTGase enzyme on the syneresis of low-fat processed cheese samples are shown in Figure 2. The findings of this study showed a significant relationship between the addition of gum and enzyme and the amount of syneresis of cheese samples ($p < 0/05$). So, with the increase in gum concentration, the syneresis of the samples decreased. This may be due to the increase in dry matter as well as the increase in water absorption and retention properties of Persian gum. In fact, with the increase in gum concentration, the trapping of water molecules in the gel network formed by the gum increases and therefore, the viscosity of the product increases and the amount of syneresis decreases [11].

On the other hand, with the increase in enzyme concentration, the percentage of syneresis first decreased and then increased. The lowest amount of syneresis reported is related to the treatment containing 0.5 U enzyme and 0.5% PG with a value of 0.53%, followed by the treatment containing 0.5 U enzyme and 0.25% PG with 1.3%. The highest syneresis level was also observed in cheese samples containing 1 U enzyme and 0% gum with a value of 5.82%, followed by the treatment containing 0 U enzyme and 0% gum with a value of 3.97%. In addition, the interaction effects of the tested variables did not show any significant effect on the amount of syneresis. By increasing the enzyme concentration in low-fat ultra-refined cheese, due to the increase in the bonds formed by the enzyme (transverse bonds and isopeptide bonds), the capacity to hold water in the rind increases. Also, the MTGase enzyme increases the water holding capacity through the polymerization of milk proteins [12].

The changes in syneresis as a result of adding Persian gum and MTGase enzyme during the storage period of sixty days can be seen in Table 2. In general, the water content of cheese samples decreased significantly until the 30th day of cold storage and then showed an increasing trend until the end of the storage period. It is possible that this increase in the separation of water-cheese is due to dense piles. Because casein molecules show high flexibility even in case of formation and have a tendency to form more compact micellar structures that lead to the separation of water cheese. Dense piles are formed spontaneously and as a result of curd condensation without applying any external force, which leads to the rearrangement of the curd protein network and the separation of water cheese [13].

Table 2. The results of analysis of variance (ANOVA) of the effect of different concentration of microbial transglutaminase (MTGase) and Persian gum (PG) on the pH and syneresis of cheese samples during the cold storage.

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Parameter	Factor	Storage time (day)		
		1	30	60
pH	MTGase concentration (U)			
	0	4.81 ± 0.09[a]	4.69 ± 0.11[b]	4.61 ± 0.06[b]
	0.50	4.82 ± 0.07[a]	4.73 ± 0.11[ab]	4.73 ± 0.10[a]
	1	4.87 ± 0.11[a]	4.84 ± 0.13[a]	4.79 ± 0.80[a]
	PG concentration (%)			
	0	4.90 ± 0.06[a]	4.84 ± 0.11[a]	4.74 ± 0.10[a]
	0.25	4.80 ± 0.05[b]	4.75 ± 0.10[ab]	4.73 ± 0.13[a]
	0.50	4.76 ± 0.05[b]	4.67 ± 0.12[b]	4.66 ± 0.93[a]
Syneresis	MTGase concentration (U)			
	0	1.31 ± 0.59[a]	5.05 ± 0.48[b]	4.23 ± 1.58[a]
	0.5	0.68 ± 0.33[b]	1.77 ± 0.80[c]	0.14 ±0.99[b]
	1	1.55 ± 0.90[a]	6.29 ± 1.02[a]	5.81 ± 2.71[a]
	PG concentration (%)			
	0	1.59 ± 0.75[a]	5.07 ± 2.24[a]	4.90 ± 2.89[a]
	0.25	1.08 ± 0.40[ab]	4.39 ± 1.93[a]	3.31 ± 3.73[ab]
	0.50	0.88 ± 0.83[b]	3.65 ± 2.16[b]	0.98 ± 0.36[b]

[DOI: 10.22034/FSCT.21.156.110]

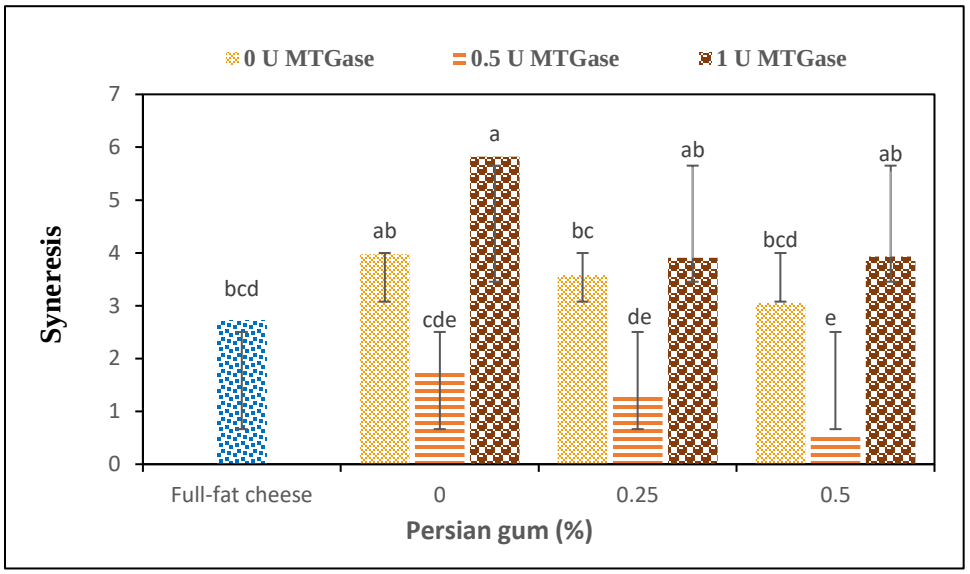

FIG. 2. Effect of different concentration of microbial transglutaminase (MTGase) and Persian gum (PG) on the syneresis of cheese samples

In another similar study, the effect of adding almond gum on the physicochemical and textural characteristics of sardine soft cheese was tested. The results of this research showed a decrease in the water level with an increase in the concentration of almond gum. According to their report, the calcium in the gum can help to form a strong casein matrix and maintain the integrity of the scab. Therefore, adding almond gum minimizes the irregularity of the micelles in the cheese matrix and, as a result, closes the pores and reduces the permeability of this dairy product [14].

3-3-Texture profile analysis (TPA)

Factors such as the components of cheese and the processing method significantly affect the texture of cheese. In general, with the reduction of the amount of fat, the firmness of cheese increases, which may cause a rubber texture in this dairy product due to the reduction of fat globules. Therefore, there is more structural matrix per unit of cross-sectional area, which causes the acceleration of flooding. In addition, the process of proteolysis plays an important role in the formation of sensory characteristics of cheese such as texture and flavor [15]. In this research, the texture of cheese samples was examined using a texture tester. The results obtained from texture profile analysis (TPA) such as hardness (N), adhesiveness (N.mm), cohesiveness, springiness (mm), gumminess (N) and chewability (N.mm) of the samples Cheese was investigated.

3-3-1- Hardness

From the sensory point of view, the hardness is the force required for the penetration of the molar teeth into the sample, and from the mechanical point of view, it is the force required to achieve a deformation [16]. In relation to cheese samples, hardness is defined based on the maximum force in the first bite. During the storage period, The lowest and the highest degree of hardness are respectively equal to N 2.33 (the sample containing 0.5% gum and 0.5 U enzyme on the first day of storage) and 4.22 (the sample containing 0.5% gum and 1 U enzyme on 30th day of storage) was measured (Table 3). Contrary to the findings obtained from this study, it has been reported that, compared to the control sample, the treatment of quark cheeses with MTGase did not cause significant changes in their hardness [5]. In another study, depending on the concentration of

[DOI: 10.22034/FSCT.21.156.110]

MTGase enzyme, a significant difference was observed between the hardness values of cheese samples. The sample with U5/g enzyme ratio of the protein had the same hardness as the control sample, but in the U2/g enzyme ratio, the hardness increased significantly. In addition to hardness, the values of springiness, adhesiveness and bite strength (chewability) of cheeses containing higher enzyme concentrations were also higher than control cheeses during the storage period [17].

In a similar research, the results of adding MTGase enzyme and whey proteins on the rheological characteristics of Iranian low-fat white cheese, a significant increase in the ratio of moisture to protein (M:P) and also a decrease in the rheological parameters of hardness such as breaking stress and showed Young's and storage moduli (G'). However, increasing the concentration of whey proteins and MTGase enzyme above the critical level resulted in the formation of a cheese matrix with lower moisture content and higher hardness indices. The results of the optimization of the process variables of the response surface method (RSM) revealed that the addition of 2.4 g of whey proteins to 1 L of milk (1.04% w/w fat) in cheese making along with 0.833 enzyme units MTGase per gram of milk protein leads to the production of low-fat products with the softest texture and the highest production yield [18].

3-3-2- Adhesiveness

In Table 3 the results obtained from the amount of adhesiveness of the tested cheese samples are shown. From a sensory point of view, the amount of force required to separate food from the roof of the mouth while eating, and from a mechanical point of view, the work required to overcome the adhesion forces between the surface of food and the surface of other substances in contact with food, is defined as adhesion. In general, cheeses with higher fat content have a weaker protein matrix, which increases their adhesiveness [19]. The findings of this research showed that the amount of adhesiveness of cheese samples during the storage period was in the range of -0.70 N.mm (the sample containing 0.5% gum and 0.5 U enzyme on the first day of storage) to -0.25 (the sample containing 0% gum and 0 U enzyme on the 30th day of storage).

In another study, the results obtained from examining the texture characteristics of synbiotic ultra-purified white cheese treated with MTGase enzyme showed that compared to the control samples, the synbiotic sample had a higher adhesiveness. In general, it can be said that food with a more open protein structure has less adhesiveness. In fact, the MTGase enzyme causes the protein network of casein micelles to become more compact by creating intra- and extra-molecular bonds, thus reducing the adhesive force in cheese. On the other hand, the higher level of adhesiveness in the synbiotic sample as well as the probiotic sample compared to the non-probiotic control sample can be due to the higher number of lactic acid bacteria and, as a result, the higher rate of proteolysis [20].

In addition, the investigation of the effect of adding almond gum on the textural characteristics of soft sardine cheese showed a decrease in the hardness and adhesiveness of the samples in different concentrations of gum compared to commercial cheeses. Treatment with almond gum also affected other textural parameters such as cohesiveness and springiness [14].

3-3-3- Cohesiveness

The strength of the internal links forming the structure of a food item is called cohesiveness. According to the results shown in Table 3, it can be said that the cohesiveness of the cheese samples decreased. The cohesiveness of the tested cheese samples was variable ranged from 0.03 (the sample containing 0.5% gum and 0 U enzyme on the 60th day of storage) to 0.54 (the sample containing 0% gum and 1 U enzyme on the first day). The results of a similar study

[DOI: 10.22034/FSCT.21.156.110]

showed that the sample of low-fat mozzarella cheese containing (w/w) 2% tragacanth gum on the 30th day of storage had the lowest (0.38) and the control sample (the sample without gum) had the highest degree of cohesiveness (0.83) which shows the important role of gum in maintaining the texture of mozzarella cheese [21].

The findings obtained from another study showed a significant increase in the cohesiveness and springiness of white cheese samples containing MTGase enzyme during the 60-day storage period, and the cheese sample containing 60 ppm of the enzyme had the highest amount. It was cohesiveness and springiness. On the other hand, the amount of adhesion of the samples decreased significantly during cold storage and the lowest amount of adhesiveness was observed in the sample containing 60 ppm of enzyme [22].

3-3-4- Springiness

In relation to the springiness of cheese samples, it can be said that from a sensory point of view, it is the degree or intensity of returning to the original state after slight pressure in the mouth, and mechanically, it is the amount of deformation that a sample of deformation It is found that after removing the force, it returns to its initial state [23]. In this study, the springiness values of cheese samples ranged from 6.55 mm (the sample containing 0.5% gum and 0.5 U enzyme on the 60th day of storage) to 8.97 (the sample containing 0% gum and 1 U of the enzyme on the first day of storage) (Table 3).

Similarly, it has been reported that the addition of MTGase to white cheeses produced with chymosin has increased springiness and chewability by 9% and 19%, respectively. In addition, the degree of adhesiveness of samples treated with enzyme was higher than that of the control sample [24]. Examining the textural characteristics of quark cheeses during the storage period showed that the springiness of all samples was at the highest level on the first day of storage, but it decreased significantly until the end of the period. The highest and lowest springiness values were observed in control sample (T0) on the first day and T3 sample (sample containing 0.3 L/g of MTGase and 0.06 L/g of lipase enzyme) on the 10th day, respectively. Unlike other samples, the springiness value of sample T3 increased significantly on the 20th day [5].

3-3-5- Gumminess

Gumminess refers to the energy required to crush a semi-solid food until it is ready to be swallowed [20]. In the same order, according to the results shown in Table 3, the gumminess of the cheese samples was measured during the storage period of N 0.94 (The sample contains 0.5% gum and 0.5 U enzyme on the first day of storage) to 2/12 (The sample contains 0% gum and 1 U enzyme on the first day of storage). The findings of another study showed a linear and significant effect of the dependent variables of different concentrations of fat, basil seeds and xanthan gum on the gumminess of low-fat cream cheese. The highest amount of gum (N 4.33) was observed in the cheese containing the lowest amount of fat (16%) and without any basil and xanthan gum; meanwhile, the lowest amount of gum (N 0.5) was measured in the sample containing 24% fat, 0.5% basil seeds and 0.5% xanthan gum. In addition, it has been found that the use of xanthan gum and low concentrations of sodium caseinate reduces the gumminess of low-fat cheddar cheese and mozzarella cheese [9].

[DOI: 10.22034/FSCT.21.156.110]

Table 3. The effect of different concentrations of microbial transglutaminase (MTGase) and Persian gum (PG) on the hardness of the cheese samples during the cold storage period (Mean ± SD)

Storage period (days)	PG concentration (%)	MTGase concentration (U)	Textural parameters					
			Hardness (N)	Adhesiveness (N.mm)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (N.mm)
1	0	0	0.07 ±3.61	0.03 ± -0.32	0.03±0.45	0.23±7.98	0.11±1.64	0.61±13.05
	0	0.5	0.08 ±3.38	0.04±-0.52	0.04±0.45	0.22±7.74	0.14±1.53	0.93±11.86
	0	1	0.09±3.91	0.03±-0.30	0.05±0.54	0.15±8.97	0.15±2.12	1.08±19.04
	0.25	0	0.09±3.15	0.03±-0.44	0.02±0.42	0.32±7.70	0.10±1.34	0.79±10.29
	0.25	0.5	0.10±2.91	0.02±-0.59	0.03±0.42	0.26±7.49	0.09±1.22	0.31±9.15
	0.25	1	0.06±3.27	0.03±-0.41	0.04±0.50	0.29±8.73	0.15±1.66	0.79±14.45
	0.5	0	0.06±2.86	0.03±-0.52	0.02±0.40	0.27±7.52	0.04±1.14	0.31±8.60
	0.5	0.5	0.12±2.33	0.04±-0.70	0.01±0.40	0.23±7.39	0.07±0.94	0.36±6.95
	0.5	1	0.07±2.98	0.04±-0.46	0.04±0.48	0.26±8.49	0.08±1.45	0.35±12.28
30	0	0	0.16±4.15	0.03±-0.25	0.03±0.42	0.31±7.91	0.04±1.77	0.29±13.98
	0	0.5	0.29 ±3.66	0.04±-0.45	0.03±0.42	0.27±7.64	0.15±1.53	0.86±11.69
	0	1	0.23±4.23	0.03±-0.28	0.04±0.50	0.06±8.87	0.21±2.11	1.80±18.75
	0.25	0	0.11±3.44	0.01±-0.29	0.01±0.39	0.45±7.69	0.07±1.43	0.69±10.32
	0.25	0.5	0.15±3.18	0.04±-0.49	0.03±0.37	0.34±7.49	0.06±1.20	0.16±8.95
	0.25	1	0.10±3.68	0.03±-0.30	0.03±0.47	0.28±8.64	0.12±1.74	0.63±15.01
	0.5	0	0.10±3.07	0.02±-0.39	0.01±0.37	0.40±7.53	0.07±1.16	0.72±8.72
	0.5	0.5	0.23±2.76	0.02±-0.53	0.03±0.40	0.27±7.31	0.17±1.12	1.37±8.17

[DOI: 10.22034/FSCT.21.156.110]

	0.5	1	0.13±3.04	0.03±-0.36	0.03±0.44	0.20±8.32	0.12±1.35	0.74±11.21
60	0	0	0.77±3.42	0.03±-0.28	0.03±0.39	0.19±7.75	0.27±1.33	2.03±10.27
	0	0.5	0.19±3.46	0.04±-0.48	0.01±0.40	0.25±7.58	0.07±1.41	0.67±10.67
	0	1	0.16±4.04	0.04±-0.33	0.03±0.46	0.13±8.71	0.15±1.89	1.50±16.44
	0.25	0	0.17±3.25	0.01±-0.32	0.02±0.37	0.17±7.31	0.04±1.21	0.12±8.86
	0.25	0.5	0.09±2.97	0.03±-0.53	0.02±0.39	0.08±7.05	0.04±1.16	0.23±8.16
	0.25	1	0.20±3.54	0.02±-0.33	0.02±0.44	0.23±8.28	0.11±1.56	0.59±12.90
	0.5	0	0.22±2.95	0.02±-0.39	0.02±0.34	0.06±7.06	0.05±1.00	0.41±7.06
	0.5	0.5	0.09±2.67	0.02±-0.60	0.00±0.36	0.91±6.56	0.04±0.96	0.28±6.29
	0.5	1	0.13±3.01	0.03±-0.39	0.02±0.40	0.14±7.70	0.06±1.21	0.25±9.34

[DOI: 10.22034/FSCT.21.156.110]

3-3-6- Chewability

Chewability is the work required to chew and knead food during swallowing, and it is calculated from the product of springiness in the amount of gumminess [20] . In this research, the lowest and highest chewability values of the tested cheese samples was6/29 N.mm (The sample containing 0.5% gum and 0.5 U enzyme on the 60th day of storage) and 19/04 (The sample contains 0% gum and 1 U enzyme on the first day of storage) (table 3). In addition, in another investigation, the hardness, cohesiveness and gumminess state of the control feta cheese sample were found to be 10.35 N, 0.28 and 3, respectively. The findings of this research showed that reducing cheese fat from 18% to 14% improved the sensory and texture characteristics of the samples, but further reduction of fat content has a negative effect on such characteristics. The reasons for these effects are the reduction of gumminess, chewability, adhesiveness, springiness and hardness.[25]. In addition, lower chewability values have been reported in softer cheeses, which is due to the less force required for chewing when the cheese texture softens. These results emphasize the relationship between chewing force and cheese strength on the importance of texture for the sensory experience during consumption [26].

4-Conclusion

Today, the prominent role of fermented foods and especially fermented dairy products in improving human health and preventing various diseases is obvious for everyone. On the other hand, consumption of high-fat food products leads to various cardiovascular diseases, high blood pressure, obesity, diabetes, etc. In addition, reducing the amount of fat in fermented dairy products has negative effects on the texture, appearance and sensory characteristics of these products. Therefore, it is possible to help solve such problems by using appropriate concentrations of hydrocolloids as fat substitutes and enzymes such as MTGase. The findings of this study revealed that compared to the control sample, the samples treated with PG have lower pH values (p<0/05). Furthermore, the addition of MTGase resulted in a significant increase in pH values (p<0/05). The pH of the samples varied between 4.64 up to 4.89. Also, based on the obtained results, the minimum and maximum hardness were measured as, N 2.33 and 4.23, respectively. The findings of this research showed the amount of adhesiveness of cheese samples during the storage period was in the range of -0.703 to -0.257 N.mm. In addition, the cohesiveness of cheese samples varied from 0.34 to 0.54. In addition, the springiness of the cheese samples were in the range of 6.56 to 8.97 mm. The gumminess content of cheese samples was measured from 0.94 to 2.12 N during the storage period. In addition, the lowest and highest chewability values were 6.29 and 19.04 N.mm, respectively. The results of the present study showed that the use of appropriate levels of Persian gum and microbial MTGase enzyme reduces the amount of syneresis of cheese samples and also improves their textural characteristics such as hardness, chewability, etc. According to the results of this research, it is possible to produce cheese with optimal quality by using the levels of 0.25 to 0.5% Persian gum and 0.5 unit of microbial MTGase enzyme.

5- Acknowledgement

The authors of the article express their gratitude to the Research and Technology Vice-Chancellor of Agricultural Sciences and Natural Resources University of Khuzestan for the financial support of this research.

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[DOI: 10.22034/FSCT.21.156.110]

مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی–پژوهشی

اثر افزودن صمغ فارسی و آنزیم ترانس‌گلوتامیناز میکروبی بر ویژگی‌های بافتی پنیر سفید فراپالودهٔ نیم‌چرب

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اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۳/۱/۷

تاریخ پذیرش: ۱۴۰۳/۲/۱۹

کلمات کلیدی:

تیمار آنزیمی،

جایگزین چربی،

آب‌اندازی،

آنالیز پروفیل بافت.

DOI:10.22034/FSCT.21.156.110.

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چکیده

هدف از مطالعهٔ حاضر بررسی تأثیر صمغ فارسی (PG) و آنزیم ترانس‌گلوتامیناز میکروبی (MTGase) بر ویژگی‌های بافتی پنیر سفید فراپالودهٔ نیم‌چرب طی مدت ۶۰ روز نگهداری در یخچال بود. بدین‌منظور، صمغ فارسی در سه سطح (۰، ۰/۲۵، و ۰/۵٪) و آنزیم ترانس‌گلوتامیناز در سه سطح (۰، ۰/۵، و ۱ واحد به ازای هر گرم پروتئین) به نمونه‌های پنیر اضافه گردید. نمونه‌های پنیر بدون هیچ‌گونه تیماری به‌عنوان نمونه‌های شاهد درنظر گرفته شدند. یافته‌های این مطالعه مشخص ساخت که افزودن PG برخلاف تیمار MTGase سبب کاهش pH گردید ($p < ۰/۰۵$). درطی دورهٔ نگهداری، مقادیر pH تمامی نمونه‌های پنیر کاهش یافت، اما از نظر آماری تنها میان روزهای اول و سی‌ام نگهداری تفاوت معناداری وجود داشت. درطی دورهٔ نگهداری، افزودن صمغ کاهش میزان آب‌اندازی نمونه‌ها را تا روز سی‌ام نگهداری به‌دنبال داشت، اما سپس تا پایان روز شصت‌ام میزان آب‌اندازی نمونه‌ها افزایش یافت. نتایج به‌دست‌آمده از آنالیز ویژگی‌های بافت مشخص ساخت که تیمار آنزیمی MTGase تا نیم واحد سبب کاهش سفتی، صمغی، ارتجاع‌پذیری و قابلیت جویدن و افزایش چسبندگی نمونه‌های پنیر شد اما به‌کارگیری مقدار بالاتر آنزیم (۱ واحد) سبب تغییر روند مذکور به‌شکل معنادار ($p < ۰/۰۰۱$) گردید. همچنین افزودن PG سبب کاهش سفتی، پیوستگی، صمغی، ارتجاع‌پذیری و قابلیت جویدن و افزایش چسبندگی نمونه‌های پنیر شد ($p < ۰/۰۰۱$). به‌طورکلی، با گذشت مدت‌زمان نگهداری سرد تمامی پارامترهای بافت به‌غیر از چسبندگی کاهش معنی‌داری یافت. نتایج این تحقیق نشان داد که می‌توان با استفاده از سطوح ۰/۲۵ تا ۰/۵ درصد صمغ فارسی و همچنین مقدار ۰/۵ واحد آنزیم ترانس‌گلوتامیناز میکروبی پنیری با کیفیت مطلوب تولید نمود.