Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

The effect of microbial transglutaminase enzyme treatment and Persian gum on the physicochemical and color characteristics of low-fat stirred yogurt

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ARTICLE INFO

Article History:

Received: 2024/8/29
Accepted:2024/10/2

Keywords:

MTG,

PG,

Physicochemical properties,

Lightness,

Storage time

DOI: 10.22034/FSCT.21.155.180.

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ABSTRACT

Among the food products, yogurt is very popular due to its distinctive characteristics such as the presence of lactic acid bacteria and nutritional and therapeutic properties. In any case, consumption of high-fat yogurt can endanger health on the one hand, and on the other hand, reducing fat reduces the quality of the product. Therefore, this research was conducted with the aim of investigating the possibility of improving the characteristics of low-fat stirred yogurt using the treatment of microbial enzyme transglutaminase (MTG) and Persian gum (PG). Low-fat stirred yogurt samples were produced using levels of 0, 0.1 and 0.2% (w/v) of PG gum and levels of 0 and 0.015% (w/v) of MTG enzyme. The physicochemical characteristics and color values of the samples were evaluated during 14 days of storage in the refrigerator. Based on the results of this research, the addition of PG and MTG enzyme significantly reduced acidity and syneresis ($p<0.05$). Furthermore, the addition of gum increased lightness and redness and reduced yellowness. Although the enzyme treatment like PG increased the lightness and redness, it caused an increase in the yellowness of the yogurt. Storage time significantly decreased syneresis and lightness parameters and increased yogurt acidity and redness and yellowness indexes ($p<0.001$). In conclusion, the results of this research showed that by using transglutaminase enzyme treatment (0.015%) and adding Persian gum (especially 0.2%), low-fat stirred yogurt with acceptable physicochemical characteristics and color can be produced and the quality of low-fat stirred yogurt can be improved.

[DOI: 10.22034/FSCT.21.155.180]

1- Introduction

Nowadays, it has been proven that continuous consumption of yogurt improves health and reduces chronic intestinal inflammation, especially by increasing immunity and regulating appetite. Yoghurt calcium plays an important role in body weight balance as a result of reducing lipogenesis, lipolysis and fat oxidation thru affecting intracellular calcium concentration (by calcitriol concentration). Also, calcium may react with other nutrients and compounds that make up yogurt, such as branched-chain amino acids, bioactive peptides, and fermentation products [1]. Dairy products contain important bioactive proteins such as immunoglobulin, alpha-lactalbumin, beta-lactoglobulin, lactoferrin and phosphopeptides, which play an important role in regulating the immune response, regulating blood pressure and facilitating the absorption of minerals. Bioactive peptides derived from casein and especially whey proteins may act as regulatory compounds or exorphins due to the proteolytic activity of dairy starters. These compounds are able to bind to the opioid receptors of the intestinal epithelial cells and cause various physiological effects in the body such as controlling social behaviors, anti-diarrheal activity and stimulating endocrine responses [2].

Due to its favorable taste and variety, yogurt, especially its high-fat type, has attracted the attention of the general public. In any case, scientific evidences and findings indicate the relationship between high fat consumption and increased risk of illness to some diseases such as obesity, hardening of the vessel wall, cardiovascular diseases, high blood pressure, tissue damage, and osteoporosis and various types of cancer [3 and 4]. With the increase in people's awareness of the dangers of fat consumption, the demand for low-fat food products, including low-fat yogurt, has increased [5 and 6]. However, removing fat from the product makes the texture and appearance undesirable and reduces the flavor [7, 8]. Therefore, it is very important to produce a low-fat product with an acceptable organoleptic characteristics liked by the consumers.

From a technical point of view in the industry, the term "gum" refers to vegetable or microbial polysaccharides and their derivatives, which can be dispersed in cold or hot water and produce viscous solutions [9]. Some of the important characteristics of gums are concentration, gel production, bonding, cohesion and emulsifying properties. In addition, gums are also important sources of dietary fibers [10]. Iran has many types of native gums. Persian gum (PG) is a type of gum that is secreted from the trunk and branches of the mountain almond tree with the scientific name *Amygdalus scoparia Spach*. Since hydrocolloids, including gums, can play a role in creating texture and mouthfeel through binding with water and affecting the appearance of the product, just like fat, it may also be used and considered as a suitable fat substitute [11].

Microbial transglutaminase enzyme (EC 2.3.3.13) is one of the transferase enzymes. First, transglutaminase enzyme was extracted from pig liver and then from cow or pig blood. The research led to the identification of a microbial source for the production of the mentioned enzyme. This enzyme is extracted and purified from an important bacterial species called *Streptoverticillium*. The optimum pH of enzyme activity is between 6 and 7 and its optimum temperature is 50°C [12]. Microbial transglutaminase (MTG) is an enzyme that, in addition to the pH drop during fermentation, heat treatment of milk also affects its reaction, and the heat process can cause its inactivation. [13]. So far, the results of many researches have shown that by using transglutaminase enzyme in dairy products such as yogurt [14], Strained yogurt [15], ice cream [16], cheese and dairy analogue products

[DOI: 10.22034/FSCT.21.155.180]

[17] the quality of these products can be improved.

Hydrocolloids, including gums, can improve the texture and mouthfeel of the product by forming a bond with the water of the product. Thus, by playing the role of some important functions of fats, these compounds can be considered as a suitable fat substitute [11]. Kuraishi et al. [18] reported that the firmness of set yogurt gel and the viscosity of stirred yogurt treated with transglutaminase had high sensory acceptability. Staffolo et al. [19] reported that in order to improve the properties of low-fat yogurts, ingredients such as gelatin, pectin, and carrageenan can be used to compensate for the problem of reducing solids in low-fat yogurts. Sanli et al. [20] added the enzyme to yogurt milk at different stages of production (after homogenization, after pasteurization and at the time of starter addition) and at two different incubation times (10 minutes and 1 hour) and showed that the addition of enzyme increased the firmness and reduced the syneresis of set yogurt. Due to the fact that the increase of dry matter can cause an unpleasant sensation in the mouth, the addition of substitutes such as transglutaminase enzyme and xanthan gum in small amounts could create better sensory properties than the added dry matter. Meanwhile, the addition of transglutaminase compared to the addition of dry matter, was able to reduce the production cost. Casein, especially sodium caseinate, is the best substrate for microbial transglutaminase among milk proteins. The ability of cross-linking between proteins in milk depends on their molecular structure [20]. Pavunc et al [21] investigated the effect of microencapsulation and transglutaminase on the survival of *Lactobacillus helveticus* and the consistency of set yogurt and reported that the pretreatment of yogurt milk with transglutaminase increases the strength of the yogurt gel and reduces syneresis and improves the appearance and consistency of the samples. Moayedzadeh et al [22] investigated the effect of transglutaminase enzyme on the viability of *Lactobacillus casei*, the physicochemical and sensory characteristics of fat-free stirred yogurt and concluded that increasing the concentration of microbial transglutaminase enzyme increases the viability of *Lactobacillus casei* and decreasing the percentage of syneresis and increasing the sensory properties of yogurt samples; therefore, it can be successfully used in the preparation of probiotic fat-free yogurt. Gol-Mohammadi et al. [23] investigated the effect of adding guar gum and Katira (tragacanth) gum on the syneresis of stirred yogurt and showed that the syneresis of samples containing hydrocolloid was lower than the control sample, and with increasing storage time, the amount of syneresis decreased. Yademellat et al. [24] investigated the effect of Shirazi balango (*Lallemantia royleana*) seed gum and Persian gum on the physicochemical and sensory properties of low-fat stirred yogurt and confirmed the potential of using these gums in improving the quality and reducing syneresis of yogurt. Unlike Persian gum, the addition of Balango Shirazi seed gum had an adverse effect on the sensory properties of the yogurt samples and significantly reduced all the sensory attributes of the yogurt samples. Jooyandeh et al. [25] investigated the effect of adding lactulose and Panirak/*Malva neglecta* (as a compound containing gum) on the sensory and microbial quality of synbiotic stirred yogurt. Scanning electron microscope evaluation showed that the addition of Panirak and lactulose resulted in maintaining more moisture in the empty spaces. In addition, the results of this research showed that with increasing the concentration of Panirak and lactulose, the count of lactic acid bacteria increased significantly.

This research was conducted in order to investigate the possibility of producing low-fat stirred yogurt using MTG enzyme treatment and different concentrations of PG gum (0, 0.1 and 0.2%, w/v), and some of the physicochemical, microbial and sensory

[DOI: 10.22034/FSCT.21.155.180]

characteristics of the produced yogurt were investigated during 14 days of storage at refrigerator temperature.

2- Materials and methods

2-1- Materials

Low-fat pasteurized milk was used to produce low-fat yogurt samples. Microbial transglutaminase enzyme (MTG) with an average activity of 100 units per gram, produced in the French company Ajintomoto, was purchased. The composition of the enzyme powder included transglutaminase, lactose, yeast extract, maltodextrin and vegetable oil. Skim milk powder was purchased from Khorasan Pegah Dairy Company. Yogurt starter culture (YF-L 811) containing *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* was purchased from DVS type manufactured by Christian Hansen Company in Denmark. In this research, the water-soluble part of Persian gum (PG) was used. Persian gum was purchased from the local market of Shiraz. After washing, first the gum was finely powdered and sieved with 60 mesh to obtain uniform particles. PG powder was continuously added to distilled water at 50 °C with stirring for 30 min and kept overnight at room temperature to complete hydration. To separate the soluble and insoluble parts, the suspension was centrifuged for 15 minutes with a force of 14000 g (HK236, Hermle, Germany) and the supernatant was separated and dried at 50°C. The dried PG was powdered and then ground and stored in polyethylene bags in the refrigerator until use [26].

2-2- Production of stirred yogurt samples

The samples of stirred yogurt were produced in the Pegah dairy factory of Khuzestan according to the method of Yademellat et al. [24] with some modifications. In order to produce yogurt samples, first, 2% of skim milk powder was added to low-fat milk (containing 1.5% fat) to increase the milk T.S. Then the milk was subjected to heat treatment at 90 °C for 15 minutes. In samples containing PG, Persian gum powder was added to the milk in different ratios (at three levels of 0, 0.1 and 0.2%, w/v) and it was mixed properly. After the heat processing and cooling the milk to 65 °C, PG was added and then the temperature of the milk was gradually cooled down to the inoculation temperature (45 °C) while stirring. In the samples containing transglutaminase enzyme, after bringing the milk temperature to 45 °C, the enzyme was added to the milk at two levels of 0 and 0.015% (w/v). In order to treatment of the milk with the enzyme, the samples were placed in an incubator at the same temperature for 1 hour. Then, in order to inactivate the enzyme, the samples were pasteurized at a temperature of 80 °C for 1 minute in a hot water bath (Bain-Marie) [27]. Next, the yogurt starter was added to the milk according to the manufacturer's instructions, and the inoculated milk samples were kept in an incubator at 42 °C for 3 hours. After the pH reached 4.6, the yogurt samples were transferred to the refrigerator with a temperature of 7 °C. One day after the production, the clots of the prepared samples were gently stirred and divided into 90 cc yogurt containers with caps. Then, the containers were moved to the refrigerator and kept for testing. The tests were carried out in two storage periods of 1 and 14 days. All tests were performed in three replications. It is worth mentioning that the levels of Persian gum and transglutaminase enzyme were determined based on preliminary tests. The sample without transglutaminase enzyme and PG was considered as control yogurt and compared with other low-fat yogurt samples during 14 days of storage. The schematic of the yogurt production is shown in Figure 1.

[DOI: 10.22034/FSCT.21.155.180]

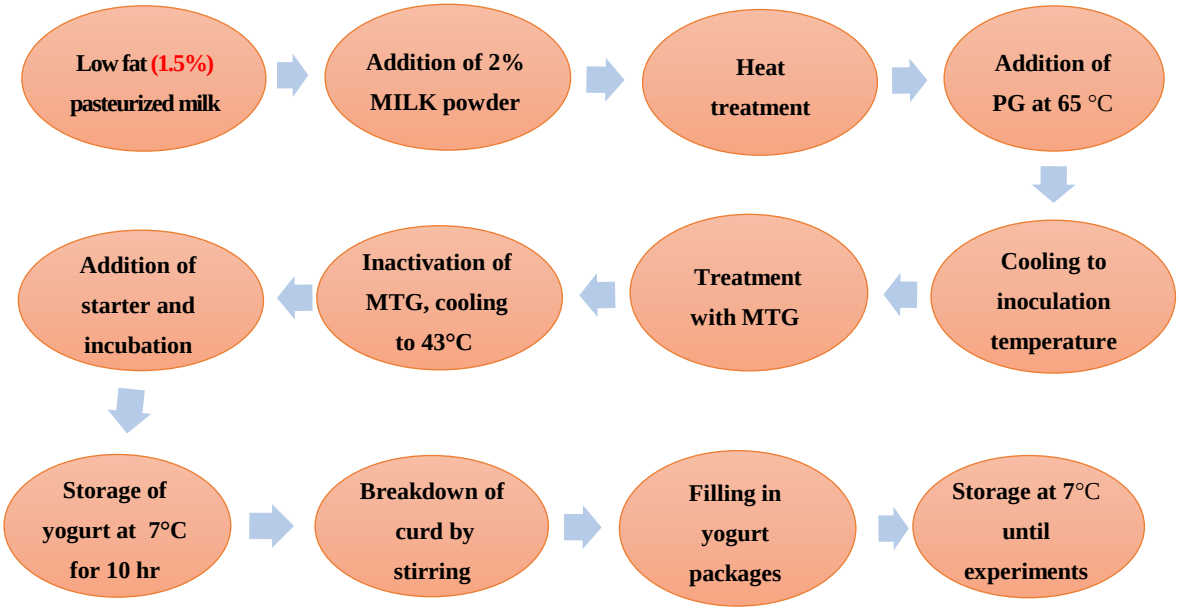

Fig. 1- Production of low-fat yogurt samples containing transglutaminase enzyme and Persian gum

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

2-3- Physicochemical analysis

Acidity was measured according to the standard method of AOAC [28]. Acidity (in terms of lactic acid percentage) was measured through the titration of yogurt samples with 0.1 normal NaOH solution in the presence of phenolphthalein reagent. The syneresis of stirred yogurt samples was determined according to the method of Ababaf et al. [17]. In order to measure the degree of syneresis, 30 to 40 grams of the yogurt samples were weighed in 50 ml centrifuge tubes (Falcons) and then the tubes were placed in a GMBH centrifuge (model Z206A, made in Germany) at 222 ×g for 10 minutes at 4 °C. After centrifugation, the weight of the clear serum released at the top of the falcon was measured. As a result, by dividing the weight of the released water by the weight of the original yogurt, the amount of syneresis was calculated as a percentage according to the following relationship:

2-4- Determination of color parameters

The color of yogurt samples was tested using a colorimeter Minolta CR400 series, Minolta Gamera Co. during 14 days of cold storage period at 4 °C; where a* (a value), b* (b value)) and L* (L value) indicate redness, yellowness and whiteness, respectively [29].

2-5-Statistical analysis

In this study, according to the production variables: amount of gum (in 3 levels) and enzyme (in 2 levels), 6 low-fat yogurt treatments were produced. All the tests were performed in two storage periods (1 and 14 days) in 3 replications. To investigate the effect of variables (gum, enzyme and storage time), the results were analyzed using completely random design in factorial format by SPSS version 20 software. To compare the averages, Duncan's multiple range test was used at the 5% level. One-way analysis was used to compare the mean of low-fat yogurt treatments. All graphs were drawn using Excel software.

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3-Results and Discussion

3-1- Evaluation of the chemical composition of milk

The chemical composition of pasteurized and homogenized milk used in the production of low-fat yogurt samples is presented in Table 1.

Table 1- The chemical composition of cow's milk used in the production of low-fat yogurt samples

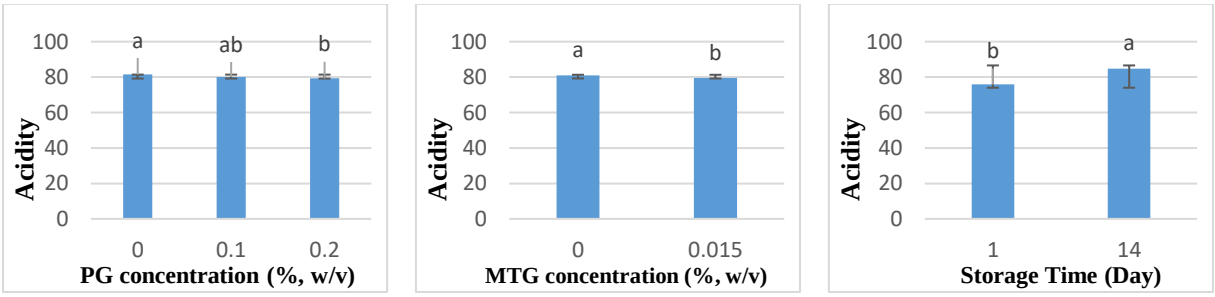
Sample	Protein (%)	Fat (%)	Milk solids non-fat	Ash
Low-fat pasteurized milk	3.25 ± 0.13	1.50 ± 0.09	8.21 ± 0.19	0.62 ± 0.04

3-2- Evaluation of the physicochemical characteristics of yogurt samples

3-2-1- Acidity

The results of the evaluation of the mean values of acidity of the yogurt samples are presented in Figure 2. According to this figure, the addition of Persian gum (PG) and microbial transglutaminase (MTG) enzyme has significantly reduced the acidity of yogurt samples. The amounts of acidity of yogurt samples containing 0, 0.1 and 0.2% PG were determined as 81.49, 80.11 and 79.28 Dornic degrees (°D), respectively (Figure 2-A). However, no significant difference was observed between the control sample and the samples containing 0.1% gum.

The reason for the decrease in acidity due to the increase in the concentration of PG gum is probably the decrease in the activity of lactic acid bacteria owing to the decrease in the amount of available water [24]. In accordance with the results of this research, Yademellat et al. reported a decrease in acidity in low-fat stirred yogurt samples as a result of increasing the concentration of Persian gum [24]. A decrease in acidity as a result of adding Persian gum in other dairy products such as kefir has also been reported [26]. Contrary to these results, Ghasempour et al. [30] reported an increase in the acidity of probiotic yogurt due to the addition of Persian gum, while they did not observe significant change on pH, and they attributed it to the buffering capacity of the gum, as a result of increasing the total solids and the amphoteric property of proteins.



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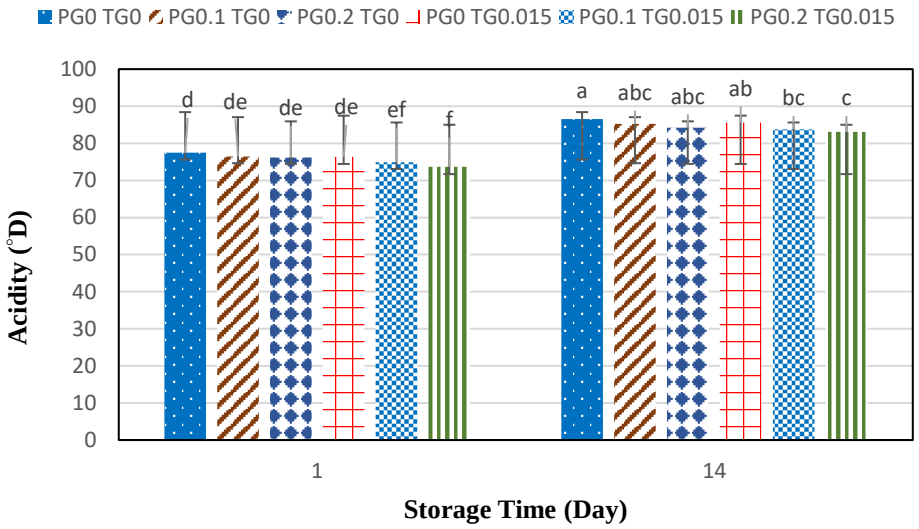


(D)

Figure 2- The influence of the independent effects of Persian gum (PG), microbial transglutaminase (MTG) enzyme, storage time, and the interaction effect of gum and enzyme (treatments) on the acidity of low-fat yogurt samples ($p<0.05$).

Based on the results of this research, the acidity of yogurt samples without MTG enzyme and containing it was determined as 81.02 and 79.55 Dornic degrees, respectively (Figure 2-B). The decrease in acidity due to the addition of MTG enzyme in low-fat yogurt samples is probably due to the establishment of cross-links between proteins as a result of enzyme activity and the trapping of peptides needed for the growth and activity of yogurt bacteria. A decrease in acidity as a result of the addition of MTG enzyme has been reported in dairy products such as yogurt [31], kefir [26], synbiotic cheese [32], and dairy analogue products such as soy yogurt [17].

The results showed that with the passage of storage time, acidity showed a significant increasing trend in all yogurt samples ($p<0.001$). The average amount of acidity in the yogurt samples increased from 75.84 °D at the beginning of the storage time to 84.74 °D on the 14th day of storage (Figure 2-C). The possible cause of the increase in acidity or decrease in pH during storage can be attributed to the extension of the lactic acid bacteria activity and acid production [17]. The decrease in acidity during the storage period of yogurt has been reported by other researchers [33 and 34].

Also, the Figure 2-D shows that there were a significant differences between the control sample and the samples containing gum and enzyme during the storage period ($p<0.001$). The highest acidity (86.54 °D) was observed in the sample without gum and enzyme at the end of storage time. The lowest level of acidity (73.65 °D) was also determined in the sample containing gum and enzyme at the beginning of the storage period.

3-2-2- Syneresis evaluation of yogurt samples

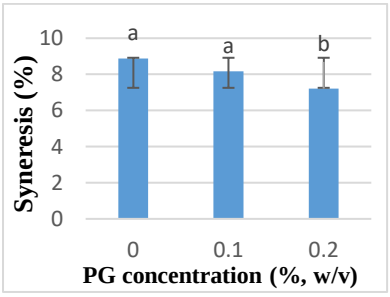
The results of the statistical analysis of the effect of three variables: PG gum, MTG enzyme and storage time on the syneresis of low-fat yogurt samples are shown in Figure 3. As can be seen in Figure 3, the independent variables had a very significant effect on the amount of syneresis in yogurt samples

[DOI: 10.22034/FSCT.21.155.180]

(p<0.01). These findings show that the increase of PG gum and MTG enzyme have reduced the amount of dehydration (Figures 3-A and B). Momenzadeh et al. [33] stated that adding cheese reduces the syneresis of the samples due to the presence of gum. The results of the research of Habibi and Jooyandeh [35] about the effect of Persian gum on ultrafiltrated white cheese were also consistent with the results of this study; with the increase of gum concentration, the amount of syneresis in the samples decreased. The decrease in syneresis of dairy products as a result of adding Persian gum is probably due to the increase of total solids and the rise of water absorption and water retention properties produced by PG. 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. In other words, the hydration of proteins by hydrocolloids causes a decrease in syneresis [36]. Based on the results of this research, the amount of syneresis of yogurt samples without gum and containing 0.1 and 0.2% was determined as 8.87%, 8.17% and 7.21%, respectively.

Similar to the effect of gum, the addition of enzyme reduced the syneresis of the yogurt samples. The amount of yogurt syneresis in samples containing 0 and 0.015 percent of enzyme was determined as 8.62 and 7.55 percent, respectively. The use of microbial transglutaminase enzyme and the reduction in gel permeability and its pore size lead to a denser and more stable structure with smaller spaces in yogurt. Therefore, most of the free water is trapped in the yogurt gel network, and in addition, the water retention capacity of the yogurt gel network is improved [20 and 37]. In similar results, Mozaffarpour Nuri et al. [38] reported that the use of transglutaminase enzyme in low-fat yogurt caused a significant reduction in syneresis.

Also, figure 3-C shows a significant difference between the syneresis value of the control sample during different storage periods (p<0.001). The average value of yogurt syneresis at the beginning and end of 14 days of storage was determined as 8.94% and 7.23%, respectively, which indicates the improvement of yogurt texture during storage. Reduction of syneresis during yogurt storage has been reported by many researchers [14, 39].



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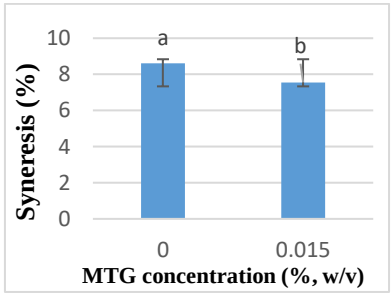

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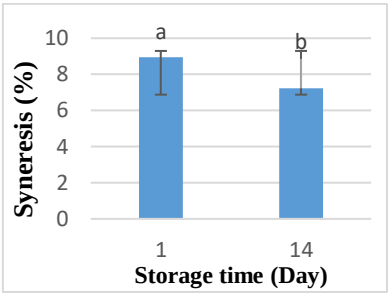

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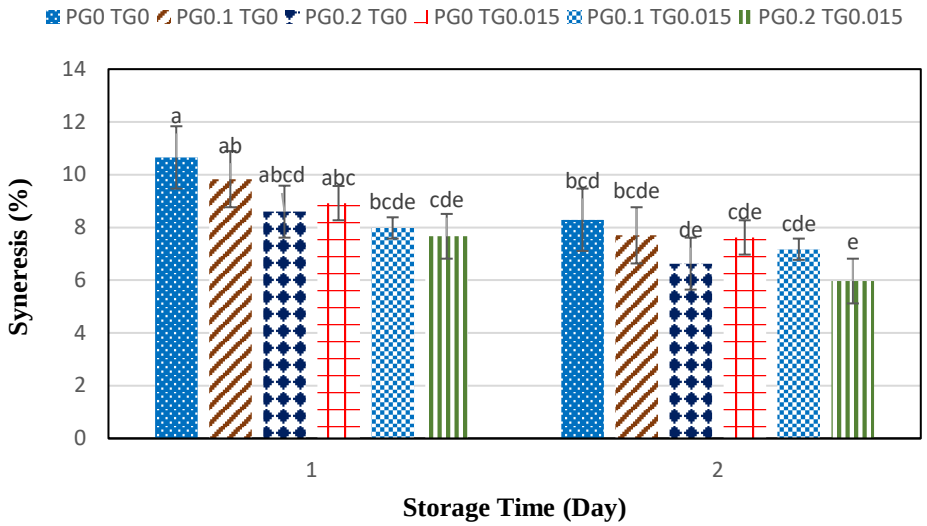


(D)

Figure 3- The influence of the independent effects of Persian gum (PG), microbial transglutaminase (MTG) enzyme, storage time, and the interaction effect of gum and enzyme (treatments) on the syneresis of low-fat yogurt samples ($p<0.05$).

The changes in yogurt syneresis as a result of adding Persian gum and transglutaminase enzyme during 14 days of storage can be seen in Figure 3-D. In general, the amount of syneresis of the yogurt samples, especially in the samples containing enzymes and gum, decreased at the end of the storage period. Thus, the highest syneresis (10.65%) was observed in the control sample (without gum and enzyme) at the beginning of the storage time. The lowest amount of syneresis (5.97%) was determined in the sample containing 0.2% gum and containing 0.015% enzyme at the end of storage time.

3-3- Evaluation of the color characteristics of yogurt samples

3-3-1- Lightness

The color characteristics of low-fat yogurt samples, including lightness (L*), redness (a*) and yellowness (b*) indexes, are presented in Figures 4 to 6. The results of the investigation of the main effects on the lightness index of the yogurt treatments presented in Figure 4 show that the yogurt treatments containing PG and MTG enzyme had higher lightness index values than the control sample, although this difference between the samples containing 0.1% PG and the control was not significant. The lightness of yogurt samples containing 0, 0.1 and 0.2 percent PG was determined as 79.47, 79.88 and 80.70, respectively (Figure 4-A). Also, the lightness value of yogurt samples without MTG enzyme and containing it was determined as 72.79 and 31.80, respectively (Figure 4-B). As mentioned before, with the increase in the concentration of PG and MTG enzyme (Figure 3), syneresis decreases significantly. Since syneresis causes the yogurt become thicker and denser structure, this reduces the scattering of light and brightness. Therefore, the increase in the concentration of PG gum and MTG enzyme is the reason for the increase in L* in treated yogurts [40]. However, Danesh et al. [41] in different results on ultrafiltrated cheese, showed that the MTG treatment causes a decrease in brightness in the

[DOI: 10.22034/FSCT.21.155.180]

cheese. This could be due to the noticeable amount of enzyme used, because at higher concentrations of the enzyme, the texture of the product becomes denser and therefore, the brightness decreases.

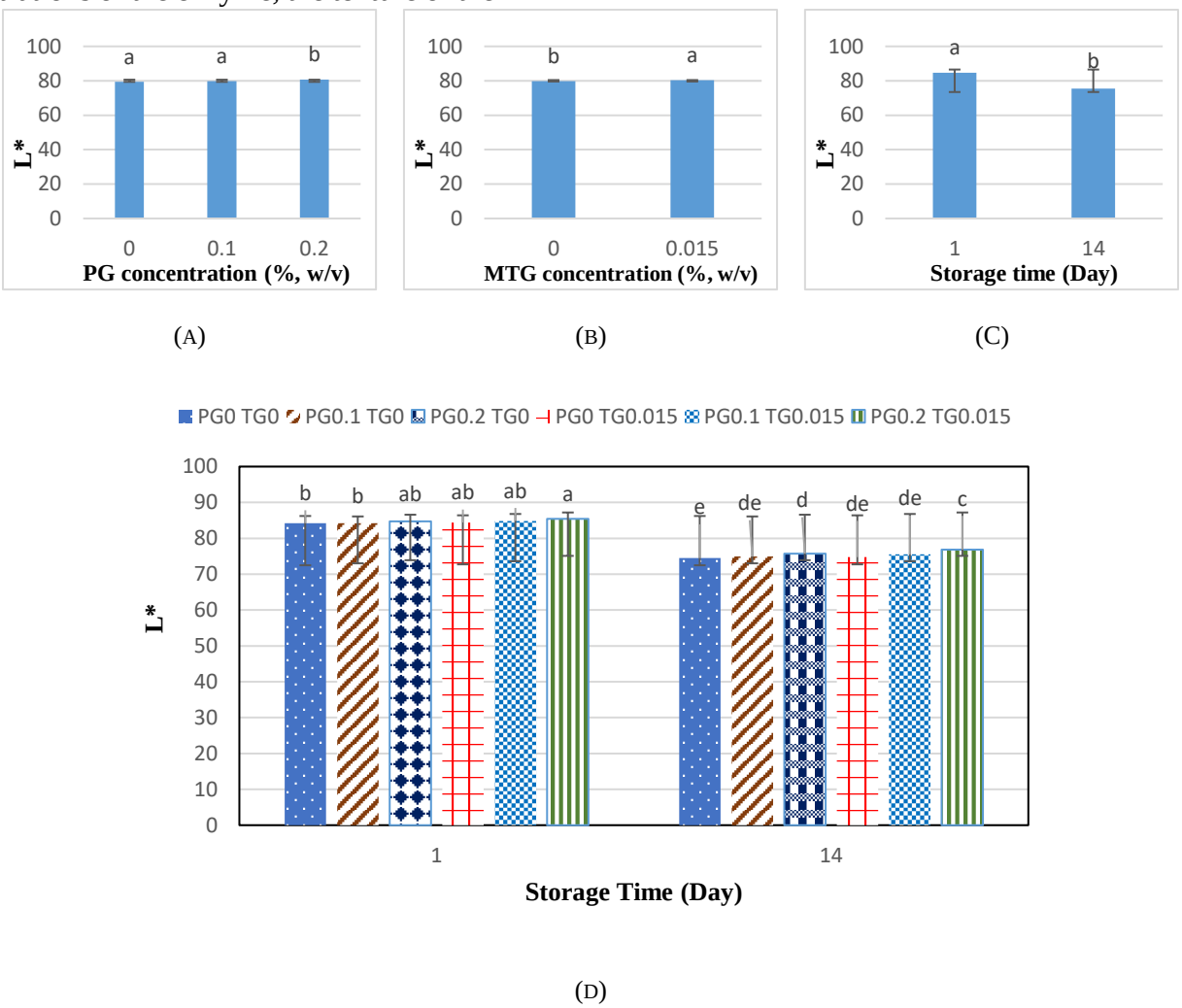


Figure 4- The influence of the independent effects of Persian gum (PG), microbial transglutaminase (MTG) enzyme, storage time, and the interaction effect of gum and enzyme (treatments) on the lightness (L*) of low-fat yogurt samples ($p<0.05$).

On the other hand, with the increase of storage time, the amount of L* index in yogurt samples decreased, so that its value decreased from 84.64 to 75.39 after 2 weeks of storage in the refrigerator (Figure 4-C). The reason for this is probably due to new interactions in the yogurt gel network during the storage period; the new conditions that led to the creation of larger accumulations of casein micelles and thereby reduction of light scattering, which result in the reduction of yogurt lightness [42]. The results obtained regarding the increase in lightness due to addition of PG or the decrease in lightness during the storage period are in accordance with the results of Yademellat et al. [24], and Rostamabadi et al. [43] and the results related to effect of MTG on lightness of yogurt is according to the results reported by Torabi et al. [44] and Bohamid et al. [36].

Also, Figure 4-D shows that there was a significant difference in terms of lightness between the control sample and the samples containing gum and/or enzyme at different

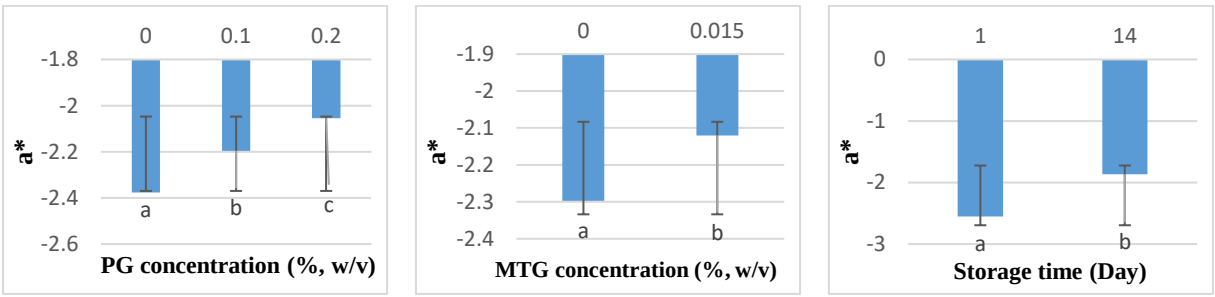
[DOI: 10.22034/FSCT.21.155.180]

storage period ($p<0.001$). The highest lightness (85.43) was observed in the sample treated with enzyme and containing the highest amount of gum at the beginning of the storage time. The lowest level of lightness (49.74) was also observed in the low-fat control sample at the end of 2 weeks of storage.

3-3-2- Redness value

The results of the statistical analysis showed that like lightness, addition of PG and MTG enzyme had a significant effect on the redness of yogurt samples and caused an increase in this factor (decrease in greenness value) ($p<0.01$). In addition, with the passage of storage time, the amount of redness of yogurt samples increased significantly ($p<0.001$) (Figure 5).

Regarding the redness index, Figure 5 showed that all treatments had a negative a* index (green color). In general, the more a* index goes to its negative side, the color of the food tends to green, and on the opposite point, the more a* goes to its positive side, the product becomes redder. According to Figure 5, the value of this index in the control sample was lower than other treatments during the storage period. As mentioned in part 3-2-2, addition of gum and enzyme as well as the passage of storage time causes a significant decrease in syneresis. Since riboflavin induces green color and syneresis in dairy products causes the release of serum containing riboflavin [45], the increase of factor a* (decrease in green color) in low-fat yogurt samples with the passage of time, can be attributed to the reduction of syneresis in these samples. In accordance with these results, Yademellat et al. [24] reported an increase in redness in low-fat stirred yogurt samples with the addition of Persian gum and with the passage of storage time. Also, Rostamabadi et al. [43] in the study of the effect of PG on the values of a* index of ultrafiltrated Iranian white cheese reported an increase of this parameter as a result of gum addition. These researchers reported the a* value of control cheese sample (without PG) was -2.2, which increased to -1.6 with the increase of PG up to 0.2%. However, contrary to these results, Bohamid et al. [36] and Torabi et al. [44] in investigating the color characteristics of synbiotic ultrafiltrated white cheese treated with microbial transglutaminase enzyme during the storage period reported that MTG enzyme treatment had no significant effect on the a* value of the product.



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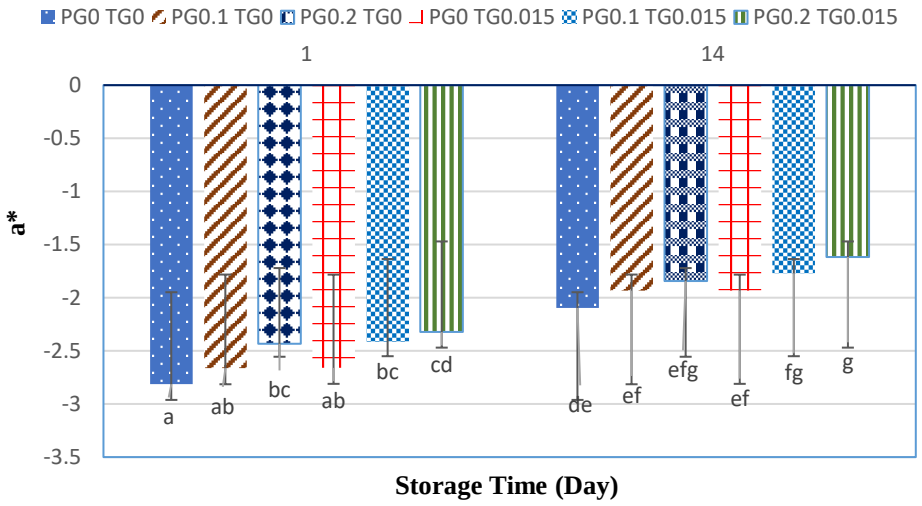


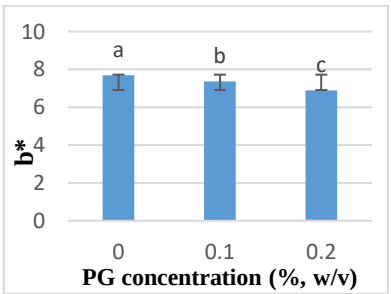
(D)

Figure 5- The influence of the independent effects of Persian gum (PG), microbial transglutaminase (MTG) enzyme, storage time, and the interaction effect of gum and enzyme (treatments) on the redness (a*) of low-fat yogurt samples ($p<0.05$).

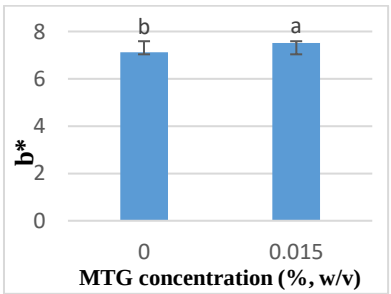
According to Figure 5-A, the a* value increased from -2.38 in the control sample to -2.05 in the sample containing 0.2% gum. Enzyme treatment with 0.015% MTG also increased this index from -3 to -2.12 (Figure 5-B). Among yogurt samples during the storage period, the lowest a* index value (-2.81) related to the control sample at the beginning of the storage period, and the highest value (-1.62) corresponds to the sample containing enzyme and 0.2% PG gum at the end of the storage period (Figure 5-D).

3-3-3- Yellowness value

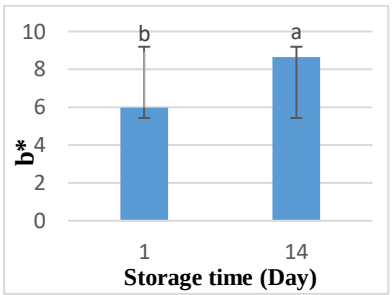
According to the results of this research, b* values of all yogurt samples were greater than zero, which indicates the yellow color of the studied samples. Like the two color factors of lightness and redness, the examined variables caused significant changes in the yellowness index of yogurt samples ($p<0.01$). However, as can be seen in Figure 6, the addition of gum and enzyme had a different effect in this field. With the increase of PG, the amount of yellowness decreased from 7.69 to 6.88, while enzyme treatment caused a significant increase from 7.12 to 7.51 (Figure 6-A and B).



(A)

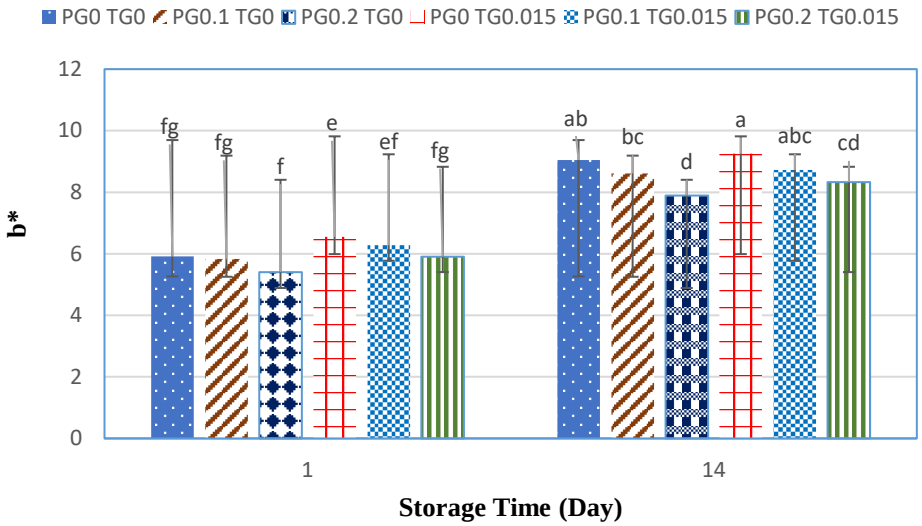


(B)



(C)

[DOI: 10.22034/FSCT.21.155.180]



(D)

Figure 6- The influence of the independent effects of Persian gum (PG), microbial transglutaminase (MTG) enzyme, storage time, and the interaction effect of gum and enzyme (treatments) on the yellowness (b*) of low-fat yogurt samples ($p<0.05$).

In similar results, Singh et al. reported an increase in the b* value and a decrease in the a* parameter due to the addition of β-glucan to yogurt [40]. On the other hand, in another study, Ramirez-Sucre and Velez-Ruiz [46] reported a decrease in the b* parameter and an increase in the a* index due to the addition of caramel flavoring and kappa-carrageenan gum to the stirred yogurt as compared to the low-fat sample. Ababaf et al also reported that with increasing enzyme concentration, the amount of yellowness of soy yogurt samples increases significantly ($p<0.001$); so that these researchers found the highest yellowness (9.23) in the treatment containing 0.045 percentage of MTG enzyme and the lowest value (8.47) were obtained for the control sample [17].

Also, with increasing storage time, the amount of b* index in yogurt samples increased significantly, so that its value increased from 5.98 to 8.64 after 2 weeks of storage in the refrigerator (Figure 6-C). The reason for this could probably be due to the Maillard biochemical reaction in the product [47] and the instability of casein micelles as a result of pH reduction [48] during storage. An increase in the yellowness parameter during the storage period has been reported by many researchers [24, 49]. According to the diagram 6-D, the highest amount of yellowness (9.05) was observed in the low-fat control sample at the end of the storage time. The lowest amount of yellowness (5.40) was observed in the sample without enzyme and containing the highest amount of gum at the beginning of the storage period.

4-Conclusion

Due to the fact that diseases such as obesity and overweight are considered as the most important problems threatening global health, consumers have fully understood the truth of the term that "prevention is better than cure". In recent decades, people have realized that they can guarantee their health by using a healthy diet. Among the consumed foods, yogurt is very popular due to its distinctive characteristics such as the presence of lactic

[DOI: 10.22034/FSCT.21.155.180]

acid bacteria and its nutritional and therapeutic properties. In any case, low-fat yogurt has lower sensory quality, especially taste and texture, compared to its high-fat samples. The purpose of using hydrocolloids in yogurt can be considered primarily to reduce water retention, improve textural properties, improve storage quality, and sometimes its appearance properties, such as yogurt syneresis. Although the use of these substances influence the taste and sensory properties of yogurt. On the other hand, the use of MTG in the formation of casein gels leads to the faster formation of gels with higher viscoelastic characteristics compared to the types obtained from acidic or rent types. Therefore, in the present study, it was tried to increase the quality of low-fat yogurt by using PG and MTG enzyme. The results showed that the MTG enzyme treatment and the addition of Persian gum (PG) improved the physicochemical characteristics and color of low-fat yogurt samples. In general, the results of this research showed that by using enzyme treatment (0.015%) and adding PG (especially 0.2%), a low-fat yogurt with acceptable physicochemical and texture properties (lower syneresis) and a superior color characteristics (higher lightness) can be produced.

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.21.155.180]

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تأثیر تیمار آنزیمی ترانس‌گلوتامیناز میکروبی و صمغ فارسی بر ویژگی‌های فیزیکوشیمیایی و رنگ ماست هم‌زدهٔ کم‌چرب

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اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۳/۶/۸

تاریخ پذیرش: ۱۴۰۳/۷/۱۱

کلمات کلیدی:

MTG،

PG،

ویژگی‌های فیزیکوشیمیایی،

روشنایی،

زمان نگهداری

DOI:10.22034/FSCT.21.155.180.

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چکیده

در میان فرآورده‌های غذایی، ماست به دلیل دارا بودن خصوصیات متمایزی نظیر دارا بودن باکتری‌های اسید لاکتیک و خواص تغذیه‌ای و درمانی بسیار پرطرفدار است. درهرحال مصرف ماست پرچرب از یک سو می‌تواند سلامت را به خطر بیاندازد، و از سوی دیگر کاهش چربی سبب کاهش کیفیت محصول می‌شود. از این‌رو این پژوهش با هدف بررسی امکان بهبود ویژگی‌های ماست هم‌زدهٔ کم‌چرب با استفاده از تیمار آنزیم میکروبی ترانس‌گلوتامیناز (MTG) و صمغ فارسی (PG) انجام پذیرفت. نمونه‌های ماست هم‌زدهٔ کم‌چرب با استفاده از سطوح ۰، ۰/۱ و ۰/۲ درصد (w/v) صمغ PG و سطوح ۰ و ۰/۰۱۵ درصد (w/v) آنزیم MTG تولید شدند و ویژگی‌های فیزیکوشیمیایی و شاخص‌های رنگ نمونه‌ها طی مدت ۱۴ روز نگهداری در یخچال بررسی شد. براساس نتایج این تحقیق، افزودن PG و آنزیم MTG موجب کاهش اسیدیته و سینرزیس به‌شکل معنی‌دار شد ($p<۰/۰۵$). به‌علاوه، افزودن صمغ سبب افزایش روشنایی و قرمزی و کاهش زردی شد. تیمار آنزیمی نیز هرچند همانند صمغ فارسی مقادیر روشنایی و قرمزی را افزایش داد، اما سبب افزایش زردی ماست گردید. زمان نگهداری هم به شکل معنی‌دار سبب کاهش مقادیر سینرزیس و روشنایی، و افزایش اسیدیته و شاخص‌های رنگ قرمزی و زردی ماست شد ($p<۰/۰۰۱$). در مجموع نتایج این تحقیق نشان داد که با به‌کارگیری تیمار آنزیمی ترانس‌گلوتامیناز (۰/۰۱۵٪) و افزودن صمغ فارسی (به‌خصوص ۰/۲٪)، می‌توان ماست کم‌چرب هم‌زده‌ای با خصوصیات فیزیکوشیمیایی و رنگ قابل قبول تولید نمود و کیفیت ماست کم‌چرب هم‌زده را ارتقا داد.