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# Production of Functional Yogurt Enriched with Oat Extract Using Microbial Transglutaminase Enzyme

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**ABSTRACT**

The yogurt production and consumption has grown significantly in recent years due to increasing consumer awareness of its effects on health. Reducing the fat percentage in low-fat yogurts can affect the product characteristics, so finding a formulation that can compensate for the effects of fat reduction while maintaining sensory characteristics is of great importance. In this study, the effect of microbial transglutaminase enzyme at two levels (0 and 0.02% w/v) and replacing oat extract with milk at four levels (0, 10, 20, and 30% v/v) on the physicochemical properties and overall acceptance of synbiotic yogurt during storage was investigated. The results showed that the use of this enzyme significantly increased the pH and reduced the acidity and syneresis of the yogurt ($p<0.01$) compared to the control sample, but had no effect on the dry matter content of the samples. Also, with increasing percentage of oat extract, the acidity and dry matter of yogurt increased and the pH of the samples decreased significantly ($p<0.01$). Also, with the passage of storage time, pH and water content decreased and acidity increased significantly ($p<0.001$), while, like the enzyme, the storage time variable did not have a significant effect on the dry matter of yogurt. Sensory results showed that, unlike the transglutaminase enzyme, increasing the percentage of oat extract caused a decrease in the overall acceptance score of the product, but no significant difference was observed in this regard between the control sample with yogurt samples containing 10 and 20 percent of barley extract. Therefore, according to the results of the study, in order to produce functional yogurt, transglutaminase enzymatic treatment (0.02 percent) and the use of 20 percent oat extract in the product formulation are recommended.

## 1-Introduction

Nowadays, one of the major concerns of food production is the prevention of nutrition-related diseases and the improvement of mental and physical performance of consumers [1]. Therefore, food industry experts are seeking to design and produce products that, in addition to desirable nutritional properties, also have specific health-promoting properties. Functional food products are among these products [2]. Given the high market potential for foods that can improve the health and well-being of consumers, interest in the development of functional foods has flourished. On the other hand, a plant-based diet is recognized as very important for the sustainability of the global food system, especially given the growth of the global population and the increasing demand for meat and dairy products [3]. Reducing meat and dairy consumption is essential for improving the environment and climate, protecting land and water resources, reducing greenhouse gas emissions, and improving human health [4]. Consumers are increasingly aware of the nutritional and health aspects of the foods they consume, which has led to the emergence of various meat and milk alternatives that cater to diverse dietary habits and religious preferences, including lactose intolerance and vegetarianism [5, 6]. Yogurt can be prepared from a variety of plant sources, such as legumes, grains, nuts, and fruits [7]. Despite the similarity of dairy-free yogurt in terms of taste, texture, and nutritional profile, this product often faces challenges in achieving desirable sensory properties. Undesirable taste (e.g., sour, sweet, bitter) and textural properties (e.g., watery, thin, separating) are among these problems [8, 9].

Oats are considered a healthy part of the diet, and new oat products have been introduced to the market as functional foods [10]. Compared to other cereals, oats are high in minerals, protein, and the essential amino acid lysine. Oats are also high in palmitic, oleic, and linoleic fatty acids. Oats have attracted much attention due to their active functional compounds called beta-glucans. Beta-glucan is a soluble fiber that has the ability to increase viscosity and can increase gastric emptying time. By increasing the time food passes through the stomach and intestines, it reduces blood glucose levels [11]. This compound is also known for its cholesterol-lowering effects [12]. Beta-glucans also have prebiotic properties, helping to nourish beneficial intestinal bacteria and improve digestive health. Considering the stimulating power of prebiotics on the growth of probiotic bacteria in the intestine and their contribution to their better shelf life during product storage, their use in the production of probiotic products seems necessary and essential [13].

Due to the increasing public awareness of the health benefits of yogurt in recent decades, its production and consumption have increased significantly. However, 70% of milk fat is saturated, which can increase blood cholesterol levels and the risk of cardiovascular diseases. For this reason, many efforts are being made to produce low-fat yogurt in a way that its properties do not differ significantly from regular yogurt. In low-fat yogurts, the textural properties of yogurt are reduced due to the reduction in fat concentration, so finding a composition that can compensate for the effects of fat reduction while maintaining organoleptic properties has received much attention [14].

The functional properties of proteins such as gelling, water-holding capacity, viscosity, thermal stability, emulsification, and foaming are influenced by the relationship between the structure and components of proteins [15]. In this regard, protein-protein crosslinks can play a very important role in improving and modifying the structural and functional properties of food proteins [16]. In recent years, the ability of the transglutaminase enzyme to improve the functional properties of proteins has been proven in various cases [15-17]. The use of TG in dairy products allows for increasing gel strength, surface viscosity, and water retention capacity. The amount of crosslinking and consistency of dairy products, including yogurt, depends on the amount of enzyme used and its strength [18].

So far, various studies have been conducted in the field of producing yogurt containing plant compounds or extracts along with transglutaminase enzymatic treatment. Bulca and Büyükgümüş in a study investigated the effect of microbial transglutaminase enzyme on yogurt-like samples prepared from peanut milk containing two different starter cultures (capable of producing exogenous polysaccharide or EPS and starter lacking the ability to produce EPS) [19]. In this study, EPS starter cultures were used to improve the consistency and viscosity of analog yogurt samples. Six analog yogurts were produced, three with YC350 starter cultures and three with YoFlex starter cultures. SDS-PAGE analysis showed that the intensity of protein bands decreased with increasing enzyme concentration. The microstructure of the analog yogurts made with EPS starter cultures had a less porous matrix, firmer and creamier structure. In sensory analyses, the analog yogurts produced with non-EPS cultures received higher scores, especially in appearance, odor and consistency. No significant changes in water holding capacity or syneresis of the yogurt samples occurred during storage. Ibrahim et al. (2017) used transglutaminase enzyme extracted from rosemary (*Rosmarinus officinalis* L.) to crosslink yogurt containing whey protein isolate (WPI) and investigated its ability to induce gelation [20]. The results of the study showed that the chemical, rheological, textural and sensory properties of enzyme-treated yogurt were better than the control yogurt. Darnay et al. also used almond, coconut and cashew proteins along with texture modifiers such as agar and microbial transglutaminase to produce plant-based yogurt alternatives [21]. In this study, the product characteristics were investigated in terms of physicochemical properties as well as rheological behavior, texture and sensory properties. The results showed that the apparent viscosity and gel stiffness were affected by the applied plant proteins and the texture modifiers were also effective depending on them. Although the use of agar resulted in higher apparent viscosity in all samples containing plant proteins, microbial transglutaminase resulted in higher gel stiffness in the case of almond and coconut yogurts, so that sensory evaluators gave higher scores in terms of smell and taste to these samples.

Given the consumer desire to consume low-fat food products with similar characteristics to high-fat products, manufacturers are looking for solutions to improve the overall quality of these products. Therefore, this study aimed to investigate the effect of microbial transglutaminase enzymatic treatment on the physicochemical properties and overall acceptance of probiotic yogurt containing oat extract during 21 days of refrigerated storage.

## 2- Materials and methods

### 2-1- Raw materials

To increase the food sources containing prebiotic compounds and increase the dry matter of yogurt, whole oat flour, a product of Aryana 111 Mazandaran Company, was used. To prepare the barley extract, barley flour and water were mixed in a ratio of 5:1 with a mixer and then the extract was extracted using a filter cloth. In this study, microbial transglutaminase enzyme (with an enzymatic activity of 100 units per gram of powder) produced by Ingredients BDF Natural, Spain, was used. DVS type yogurt starter powder (Chr. Hansen, ABY-10, made in Denmark), containing yogurt starter bacteria (*Lactobacillus delbrueckii* subspecies *bulgaricus* and *Streptococcus* *thermophilus*) and probiotic bacteria (*Lactobacillus acidophilus* LA5 and *Bifidobacterium bifidum* BB-12) was purchased from the Christian Hansen representative in Denmark in Iran. Yogurt samples were prepared using fresh low-fat milk (1.5% fat).

## 2-2- Method for preparing probiotic yogurt samples

To prepare the test samples, pasteurized low-fat milk with 1.5% fat and 8% dry matter was used. Yogurt samples were prepared according to the method of Yademellat et al. with minor modifications [22]. In this procedure, 2% dry milk was initially added to raw milk along with 0.01% xanthan gum, then heat treatment was performed at 90°C for 10 minutes. Barley extract was also heated separately under similar conditions and added to milk at three levels of 10, 20, and 30% by volume. After that, the mixture was cooled to 45°C. After adding transglutaminase enzyme at a level of 0.02% w/v, probiotic microbial strain and starter were also added at a level of 0.01% (w/v). Then, the yogurts were packed in 100-gram containers and after incubation for approximately three hours, they were placed in a refrigerator at 5°C and stored overnight. Finally, the yogurt samples were evaluated on days 1, 11, and 21. It is worth noting that the appropriate amounts of xanthan and transglutaminase enzyme were determined through preliminary tests. In the preliminary tests, based on the research conducted on the recommended amounts of xanthan and transglutaminase enzyme in yogurt production, an appropriate ranges of these two substances (0.005 to 0.02 percent xanthan and 0.01 to 0.03 percent transglutaminase enzyme) were selected. After the production of the initial samples and based on the sensory score, the best appropriate levels (0.01 xanthan and 0.02 percent enzyme) were selected.

## 2-3- Experiments

### 2-3-1- pH measurement

The pH value of the samples was measured using a digital pH meter, model Metrohm-780, made in Switzerland, in accordance with the AOAC procedures [23].

### 2-3-2- Acidity measurement

To measure acidity, the titration method with sodium hydroxide solution was used, in accordance with the AOAC methods. In this procedure, the sample and distilled water were weighed in a ratio of 1:1 in a glass beaker, then 2 to 3 drops of phenolphthalein solution were added as an indicator. Next, the final mixture was titrated with one-ninth normal sodium hydroxide solution until a pale pink color appeared. The volume of sodium hydroxide used was recorded and the acidity percentage was calculated based on the amount of lactic acid [23].

### 2-3-3- Dry matter measurement

The amount of total dry matter was measured using the oven method at 115 °C and was calculated according to the AOAC guidelines using the following formula [23].

Total dry matter percentage = (dry sample (g) / wet sample (g)) × 100

### 2-3-4- Syneresis measurement

The syneresis rate of the samples was measured according to the method of Farnworth et al. (2006) [24]. In this method, about 31 g of the sample was weighed into a 51 ml Falcon tube. Then, the tubes were centrifuged at 2511 rpm for 11 minutes. After this step, the weight of the separated serum at the top of the test tube was measured. The syneresis rate of the samples was calculated using the following equation.

syneresis percentage = (Serum weight separated from the sample (g) / Initial weight of the sample (g)) × 100

### 2-3-5- Evaluation of the overall acceptance of the samples

In this section, the overall acceptance of the yogurt samples was examined. The samples were compared using a 9-point hedonic test. The samples were randomly presented to the evaluators. Before evaluation, the samples were removed from the refrigerator for 30 minutes and kept at room temperature so that the temperature of all samples remained the same during evaluation [22].

### 2-4- Data Analysis

In this study, 8 treatments were produced, considering the two variables of microbial transglutaminase enzyme (at two levels of 0 and 0.02%) and replacing oat extract with milk (at four levels of 0, 10, 20 and 30%). All treatments were produced in 3 replications and the stated characteristics were examined at 3 storage times (1, 11 and 21 days). Therefore, 72 samples were produced in this study. The average data results were analyzed as a factorial in a completely randomized design with the help of SPSS software. Comparison of means was also performed by Duncan's test at a confidence level of 95%.

## 3- Results and discussion

### 3-1- Physicochemical properties of yogurt

### 3-1-1- pH and acidity of yogurt

According to the results of variance analysis in Table 1, each of the variables microbial transglutaminase enzyme, oat extract and storage time had a significant effect on the pH and acidity of yogurt ($p<0.01$), but their interaction was not significant. Figure 1 shows the effect of different factors on the pH of yogurt. As can be seen in this figure, with the use of the enzyme, the pH of yogurt has increased significantly compared to the control sample. Figure 2 also shows the effect of all three factors oat extract, transglutaminase enzyme and time on the acidity of yogurt. Based on the results obtained, with the use of transglutaminase enzyme, the acidity of yogurt has decreased significantly compared to the control sample (Figure 2-c). In a study, Aprodu et al. (2011) also reported higher values for the pH of samples treated with transglutaminase enzyme [25]. According to these researchers, the fermentation time in samples containing the enzyme was higher to reach the final pH, and in fact, this time was directly related to the enzyme concentration. Like pH, the acidity of the samples was affected. Mahmood and Sebo (2012) reported that the effect of enzyme treatment on pH and acidity was proportional to the added enzyme concentration [26], so that the highest pH value was related to the samples containing the highest enzyme concentration. These researchers attributed the decrease in acid production as a result of enzyme treatment to the crosslinking created by transglutaminase. Also, according to their results, a significant decrease in the pH of the samples was observed during storage. However, the results of the research by Wróblewska et al. (2009) showed that the transglutaminase enzyme has no effect on the pH of the produced product and does not cause any significant change in the rate of acid production [27]. Jooyandeh et al. (2022) reported an increase in the pH of yogurt prepared from a mixture of cow and buffalo milk due to the use of the transglutaminase enzyme [28].

**۳-۱Table 1 Analysis of variance for the effect of Oat extract, Transglutaminase enzyme and time on the physicochemical properties and acceptability of yogurt samples during storage time**

| Variable sources | Mean square |
|---|---|

| | df | pH | Acidity | Dry matter | Syneresis | Acceptability |
|---|---|---|---|---|---|---|
| Oat Extract | 3 | $0.031^{***}$ | $0.001^{**}$ | $1.944^{***}$ | $20.08^{***}$ | $0.565^{*}$ |
| Enzyme | 1 | $0.052^{***}$ | $0.005^{***}$ | $0.004^{ns}$ | $43.49^{***}$ | $0.633^{*}$ |
| Time | 2 | $0.190^{***}$ | $0.055^{***}$ | $0.038^{ns}$ | $112.21^{***}$ | $5.695^{***}$ |
| Enzyme*Oat Extract | 3 | $0.001^{ns}$ | $0.000^{ns}$ | $0.008^{ns}$ | $0.511^{ns}$ | $0.004^{ns}$ |
| Time*Oat Extract | 6 | $0.001^{ns}$ | $0.000^{ns}$ | $0.011^{ns}$ | $0.897^{ns}$ | $0.009^{ns}$ |
| Time*Enzyme | 2 | $0.002^{ns}$ | $0.000^{ns}$ | $0.005^{ns}$ | $0.470^{ns}$ | $0.024^{ns}$ |
| Time*Enzyme* Oat Extract | 6 | $0.000^{ns}$ | $0.000^{ns}$ | $0.013^{ns}$ | $0.949^{ns}$ | $0.003^{ns}$ |
| Error | 24 | 0.001 | 0.000 | 0.026 | 1.0678 | 0.127 |
| CV (%) | - | 0.300 | 0.830 | 0.630 | 0.800 | 5.080 |

ns, *and ** and *** means non-significant, and significant at 5%, 1% and 0.1%.

According to Figure 1-a, with increasing the percentage of oat extract in the samples, the pH of yogurt decreased significantly; so that with the use of 10, 20 and 30% oat extract, the pH of yogurt decreased from 4.47 (control sample) to 4.44, 4.39 and 4.35, respectively. Also, as can be seen in Figure 2-a, with increasing the percentage of oat extract in the samples, the acidity of yogurt increased significantly, so that with the use of 10, 20 and 30% oat extract, the acidity of yogurt increased from 0.79% in terms of lactic acid (control sample) to 0.8, 0.81 and 0.81%, respectively. The reason for the decrease in pH and increase in acidity due to the increase in the concentration of oat extract may be related to the prebiotic effect of oat extract on improving the activity and growth of probiotic bacteria, which has been previously reported by other researchers [29, 30]. In other words, with the increase in the activity of probiotic bacteria, the production of acidic metabolites resulting from their activity increased, which could contribute to the increase in acidity and decrease in the final pH of the product. In line with the results of this study, Demir et al. (2021) reported that with the increase in oat extract in ice cream, the acidity increased significantly [31]. Also, Alqahtani et al. (2021) reported that adding oat extract to probiotic yogurt increased lactic acid production, reduced fermentation time, and increased acid production [32]. Contrary to these results, Anli et al. (2023) investigated the effect of oat extract as a fat substitute in low-fat molded yogurt. The results of this study showed that using oat extract as a fat substitute did not have a significant effect on pH, which was inconsistent with the results of this study [33].

**(a)** **(b)**

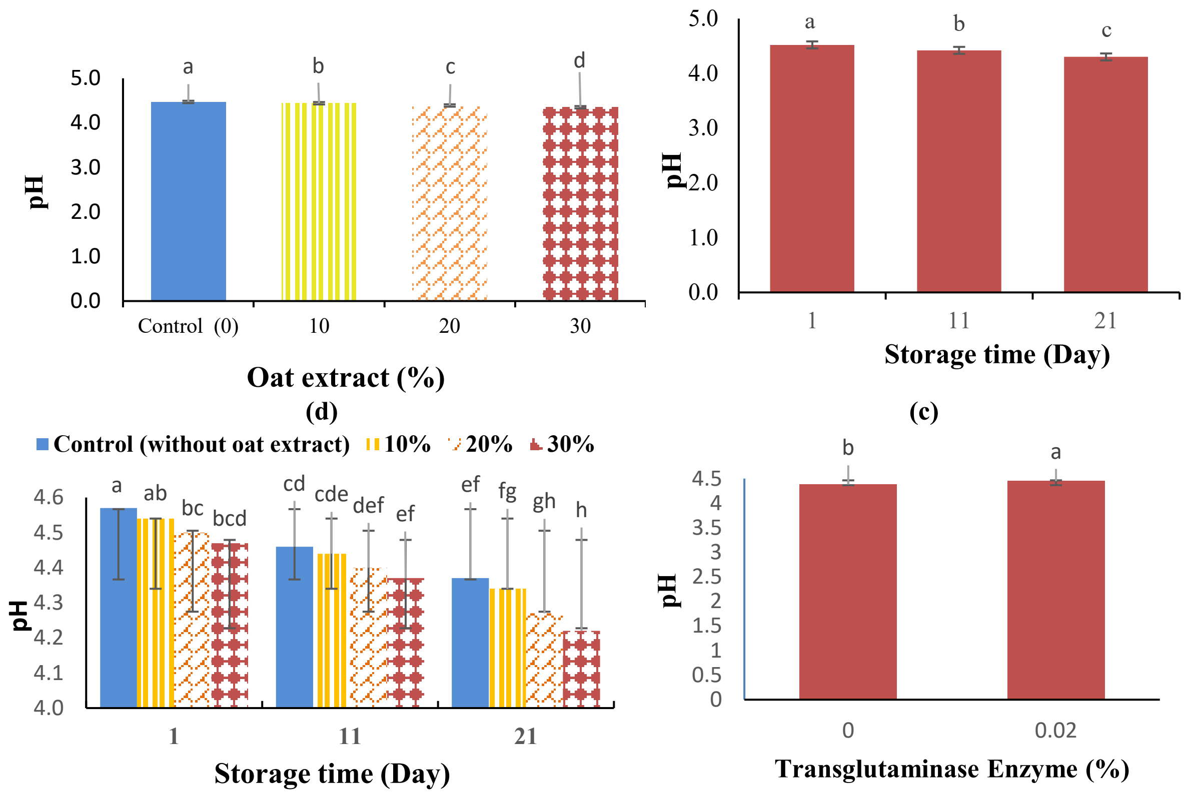



**Figure 1**. The effect of Oat extract (a), Transglutaminase enzyme (b) and time (c) on the pH of the probiotic yogurt samples

As can be seen in Figure 1-b, the pH of yogurt decreased with increasing storage time; the highest pH of yogurt (4.52) was observed on the first day of storage and the lowest (4.30) on the 21st day of storage. According to Figure 2-b, it can be seen that with increasing storage time, the acidity of yogurt increased compared to the day of production; the lowest acidity of yogurt (0.738%) was observed on the first day of storage and the highest (0.850%) was observed on the 21st day of storage. Considering the passage of storage time and the natural process of acidification of yogurt due to the activity of lactic acid bacteria and the production of lactic acid, this decrease in pH is not far from expected [34]. Bangar et al. (2022) reported that microorganisms consume proteins and organic acids in the environment when sugar resources are exhausted at the end of the storage period, which reduces the acidity of the product [35]. Torabi et al. (2021) evaluated the physicochemical, rheological, microstructural, and microbial properties of synbiotic ultrafiltrated white cheese treated with transglutaminase enzyme in a study and reported that the pH of the cheese decreased significantly during the storage period (60 days); however, according to their results, the overall use of the enzyme increased the pH during the storage period [36]. According to Fig. 1-d and 2-d, the sample containing 30% barley extract had the lowest pH (4.22) and the highest acidity (0.861% in terms of lactic acid) on day 21 of storage, while the control sample had the highest pH (4.57) and the lowest acidity (0.724% in terms of lactic acid) at the beginning of the storage period.

**(a)** **(b)**

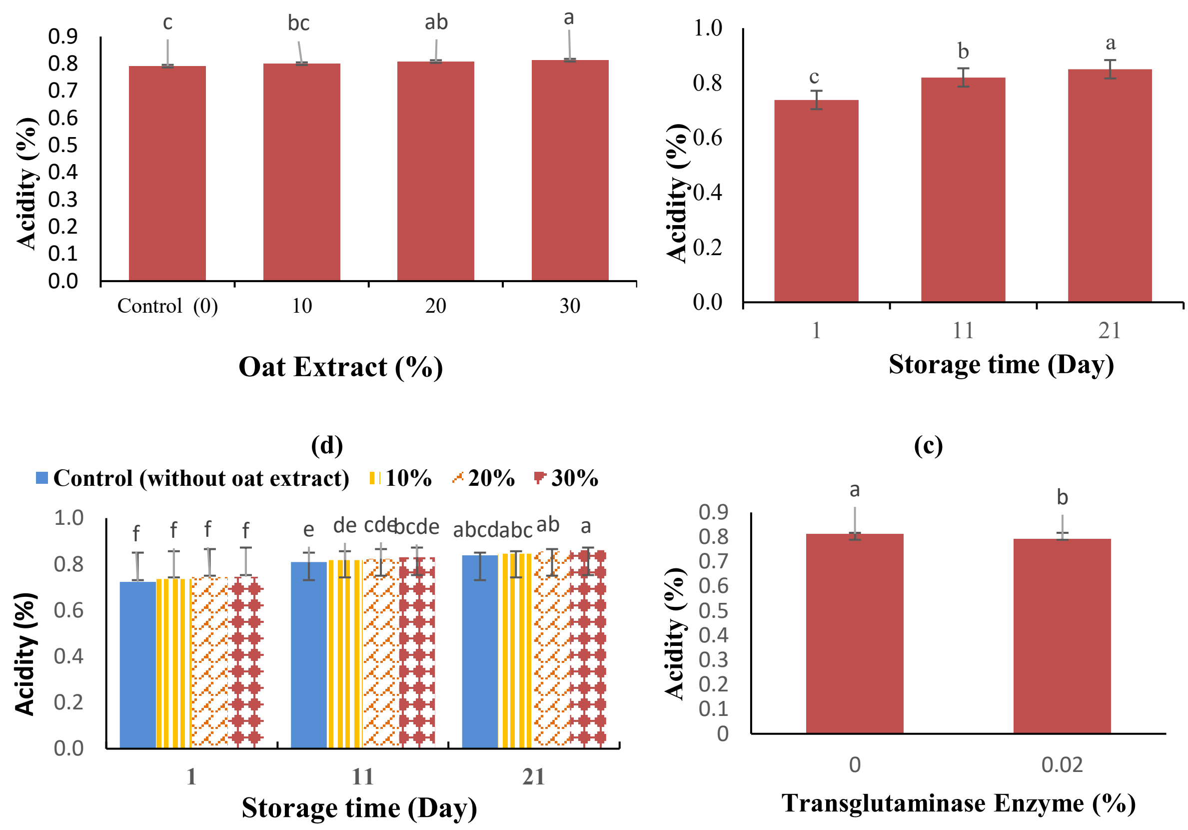



**Figure 2.** The effect of Oat extract (a), Transglutaminase enzyme (b) and time (c) on the acidity of the probiotic yogurt samples

### 3-1-2- Total solids of yogurt

According to the results of analysis of variance (Table 1), only the simple effect of oat extract had a significant effect on yogurt dry matter ($p<0.001$) and other factors and their interaction had no significant effect on this variable ($p<0.05$). Figure 3-a shows the effect of oat extract concentration on yogurt dry matter. According to this figure, with increasing percentage of oat extract in the samples, yogurt dry matter also increased, so that the use of 10, 20 and 30% oat extract increased yogurt dry matter from 12% in the control sample to 12.35, 12.62 and 12.95%, respectively. The increase in yogurt dry matter was predictable along with the increase in percentage of substitution with barley extract because barley extract dry matter (12.63%) was used more than milk dry matter (9.5%). Aryana and Megrew (2007) also reported that adding inulin to soy yogurt formulation increased the dry matter of yogurt, which they attributed to the high water retention capacity of inulin and consequently improved product viscosity [37]. Brückner-Gühmann et al. (2019) also reported that increasing the concentration of oat extract increased the dry matter of soy yogurt, but it did not affect the fat and protein content of the samples [38]. Jooyandeh and Alizadeh (2024) stated in their study that increasing the amount of bell pepper extract in functional yogurt formulation increased the dry matter percentage of yogurt, which these researchers also attributed to the higher dry matter percentage of the extract (30%) [39]. According to Figures 3-b and 3-c, the enzyme variables and storage time did not have a significant effect on the dry matter content of the yogurt samples. According to Figure 3-d, the sample containing 30% barley extract had the highest (13.02%) dry matter content at the end of the 21-day storage period, and the control sample had the lowest (11.99%) dry matter content at the beginning of the storage period.

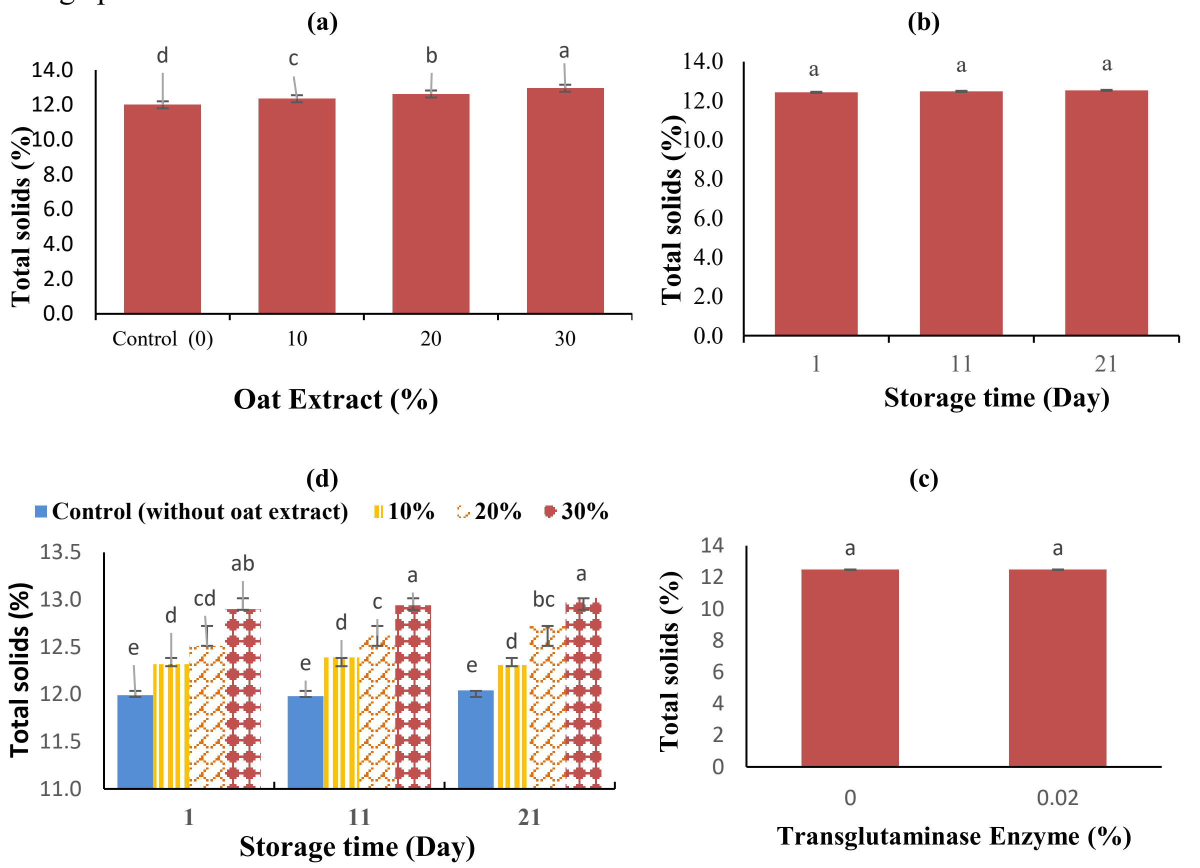



**Figure 3.** The effect of Oat extract (a), Transglutaminase enzyme (b) and time (c) on the dry matter percentage of the probiotic yogurt samples

### 3-1-3- syneresis of yogurt

As can be seen in Table 1, like the pH and acidity factors, all three variables of microbial transglutaminase enzyme, oat extract and storage time had a completely significant effect ($p<0.001$) on the amount of syneresis of yogurt, but the interaction of these variables was not significant. The effect of different factors on the amount of syneresis of yogurt is shown in Figure 4. As can be seen (Figure 4), the amount of syneresis in yogurt samples containing transglutaminase enzyme decreased compared to samples without enzyme. The decrease in syneresis, with increasing enzyme concentration, is due to the improvement of the structure of the protein network of yogurt as a result of the activity of the transglutaminase enzyme. In other words, with enzyme treatment, a protein network with smaller pores is formed, which reduces the permeability of the protein network and can retain more free water within it [40]. In fact, transglutaminase improves the water retention capacity of the casein network [14, 16]. In support of this study, Farnworth et al. (2006) showed that the water loss of probiotic yogurt from goat milk treated with transglutaminase was reduced compared to untreated samples [24]. Tsevdou et al. (2013) also reported that the percentage of serum isolated from yogurt samples treated with transglutaminase was significantly reduced compared to untreated samples. These researchers did not report significant changes in the water loss of the samples during storage [40].

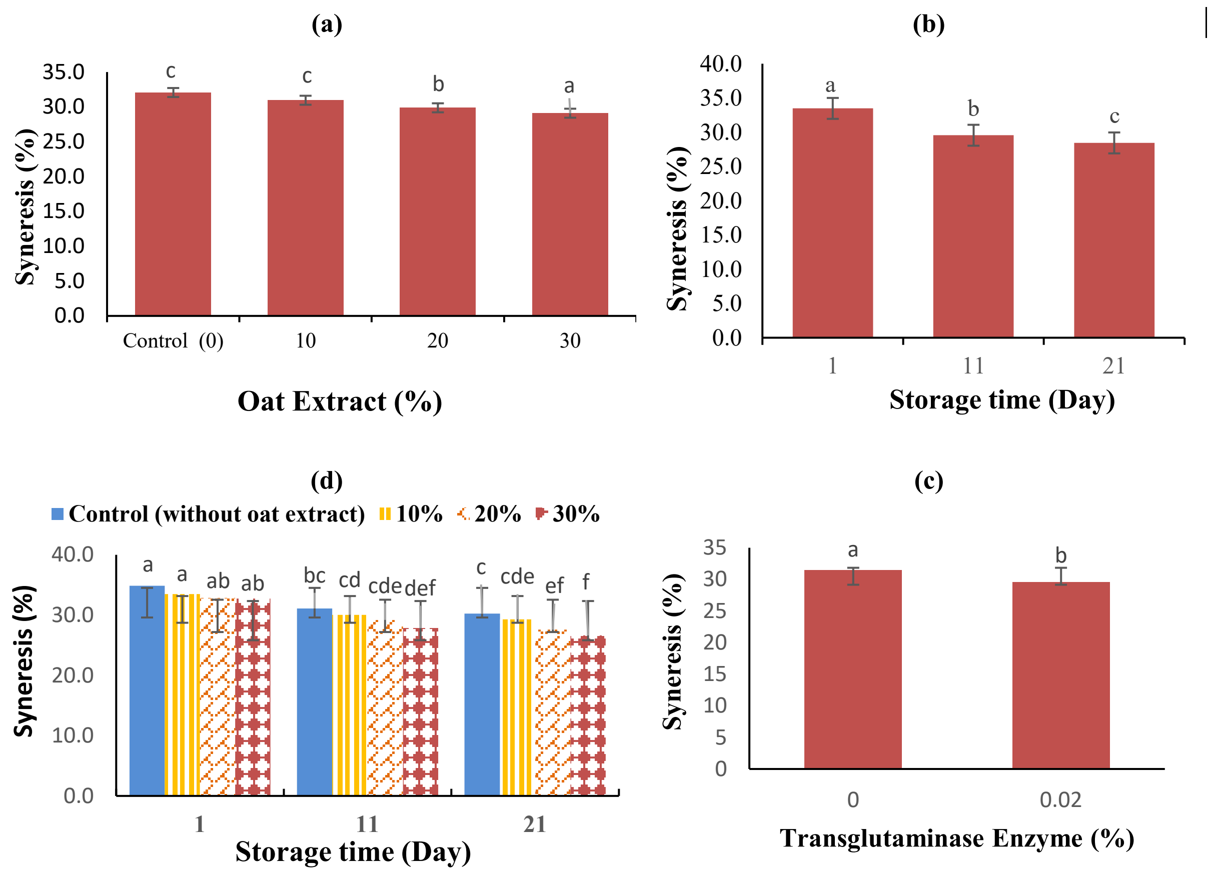



**Figure 4.** The effect of Oat extract (a), Transglutaminase enzyme (b) and time (c) on the syneresis (%) of the probiotic yogurt samples

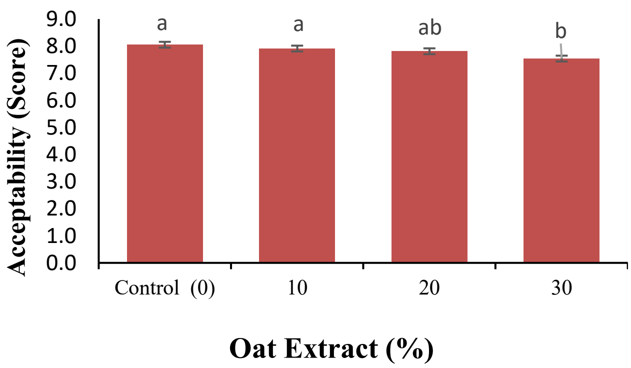
According to Figure 4-a, with increasing the percentage of oat extract in the samples, the syneresis of yogurt decreased; so that by adding 10, 20 and 30% oat extract, the syneresis of yogurt decreased from 32.06% (control sample) to 30.95, 29.87 and 29.09%, respectively. The water absorption property of oat extract due to the presence of soluble fiber could be the reason for this decrease; because this substance inhibits part of the water separated from yogurt [41]. However, Dhakal et al. (2024) evaluated the effect of long-chain oat extract on the physicochemical and microbial properties of probiotic yogurt containing *Lactobacillus paracasei* in a study and observed that adding oat extract increased the syneresis of yogurt, which was inconsistent with the results of this study [42]. In a study of the properties of oat synbiotic yogurt containing microencapsulated bacteria, Luca and Oroian (2022) reported that by combining prebiotic compounds including oligofructose, inulin, and soluble potato starch in capsules, it is possible to produce yogurt with similar quality in terms of sensory properties and texture to the control yogurt, thus reducing the negative effect of oats. In addition, this method can increase the number of probiotic bacteria in yogurt during storage [43].

As can be seen in Figure 4-b, the highest water loss of yogurt (33.48%) was on the first day and the lowest (28.44%) was on the 21st day of storage in the refrigerator. During storage of yogurt, due to the gradual decrease in pH, the protein network is formed irregularly and non-uniformly, which results in the hydrophobic groups of proteins being located on the surface of the gel network, which increases water loss at the end of storage [44]. This issue could be one of the important reasons for the decrease in water loss of yogurt during storage. However, different results have been reported regarding changes in water loss during the storage period of yogurt. Alirezalu et al. (2015) stated in their study of the production of functional colored yogurt that the amount of water loss in all yogurt samples increased with time [45], while Jooyandeh et al. (2015) pointed out a decrease in water loss of yogurt samples with time [46]. According to Figure 4-d, the sample containing 30% barley extract had the lowest syneresis (26.63%) at the end of the 21-day storage period, and the control sample had the highest dry matter content at the beginning of the storage period (34.85%).

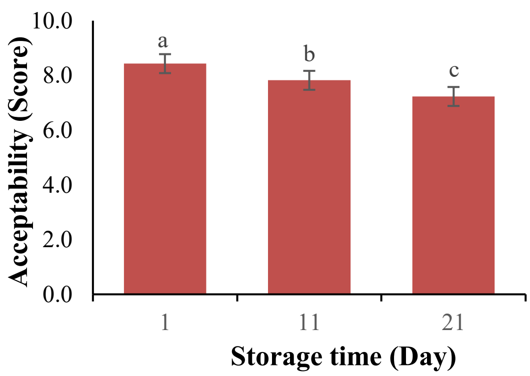
### 3-2- Overall acceptance of yogurt

The results of the analysis of variance related to the overall acceptance factor of the product is given in Table 1. As can be seen in the table, the enzyme and oat extract factors had a significant effect on the overall acceptance of the yogurt samples ($p<0.05$), while their interaction effects were not significant ($p<0.05$). The effect of different factors on the overall acceptance score of the samples is shown in Figure 5. As can be seen in this figure, the overall acceptance score of the samples containing the transglutaminase enzyme was higher than the samples without the enzyme. According to Figure 5-a, with an increase in the percentage of oat extract, the overall acceptance score of the sample increased, so that with the use of 10, 20 and 30% of oat extract, the overall acceptance score of the yogurt samples increased by 2.81, 7.02 and 11.37% compared to the control sample. As can be seen (Figure 5-b), the overall acceptance score of the samples decreased over time, so that the highest scores of the yogurt samples were on the first day (8.41) and the eleventh day of storage (8.33), respectively, which did not differ significantly from each other ($p<0.05$). The lowest score (8) was observed on the twenty-first day. Jooyandeh and Alizadeh (2024) stated in similar results that adding different colored bell pepper plant extracts to the functional yogurt formulation, although it did not cause a significant difference at the beginning of the storage time, caused the control sample (yogurt without plant extracts) to be more acceptable at the 11th and 21st days of storage [39]. According to Figure 5-d, the sample containing 30% barley extract had the lowest overall acceptance score at the end of the 21-day storage period (6.93 points), and the control sample had the highest overall acceptance score at the beginning of the storage period (8.58).

(a)




(b)




(d)

(c)

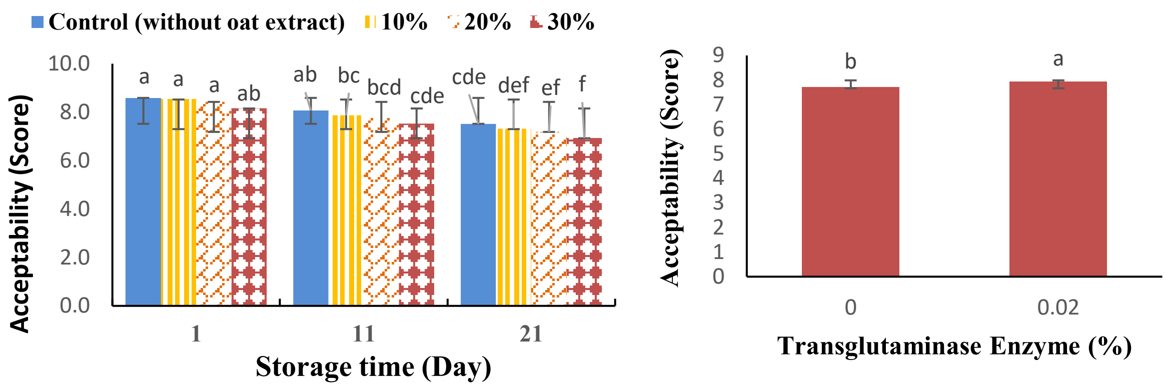



**Figure 5.** The effect of Oat extract (a), Transglutaminase enzyme (b) and time (c) on the total acceptability of the probiotic yogurt samples

## 4- Conclusion

In this study, low-fat yogurt containing different amounts of oat extract was produced along with microbial transglutaminase enzymatic treatment, and the effects of these factors on the physicochemical properties and overall acceptance of the samples were evaluated. Physicochemical results showed that with increasing enzyme concentration, the acidity and water content decreased and the pH value increased significantly; while no significant effect was observed on dry matter. Also, increasing the concentration of oat extract significantly increased the acidity and dry matter and decreased the pH and water content of the yogurt samples. The effect of storage time on the physicochemical properties of the yogurt samples showed that with the passage of storage time, the pH and water content decreased significantly and the acidity value increased. This was while no significant change was observed in the dry matter content. Examination of the sensory properties showed that with the use of transglutaminase enzyme, the overall acceptance score decreased; while increasing the percentage of oat extract increased the overall acceptance score of the samples. Therefore, it can be concluded that by using oat extract, in addition to increasing the nutritional value of the most widely consumed fermented product in Iran, namely yogurt, a low-fat product with desirable sensory properties can be produced.

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مقاله علمی_پژوهشی

# تولید ماست فراسودمند غنی شده حاوی عصاره جو دوسر با کمک تیمار آنزیمی ترانس‌گلوتامیناز میکروبی

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**چکیده**

با افزایش آگاهی عمومی نسبت به فواید ماست کم‌چرب در سال‌های اخیر، میزان تولید و مصرف این محصول رشد قابل توجهی داشته است. کاهش درصد چربی در ماست‌های کم‌چرب می‌تواند بر ویژگی‌های محصول تأثیرگذار باشد، بنابراین یافتن فرمولاسیونی که بتواند ضمن حفظ ویژگی‌های حسی، اثرات کاهش چربی را جبران کند، از اهمیت بالایی برخوردار است. در این پژوهش، تأثیر آنزیم ترانس‌گلوتامیناز میکروبی در دو سطح (۰ و ۰/۰۲ درصد وزنی-حجمی) و جایگزینی عصاره جو دوسر با شیر در چهار سطح (۰، ۱۰، ۲۰ و ۳۰ درصد حجمی-حجمی) بر خواص فیزیکوشیمیایی و پذیرش‌کلی ماست سین‌بیوتیک طی دوره نگهداری بررسی گردید. نتایج نشان داد که استفاده از این آنزیم باعث افزایش pH و کاهش میزان اسیدیته و آب‌اندازی ماست به شکل معنی‌دار ($p<0.01$) نسبت به نمونه شاهد شد اما تأثیری بر مقدار ماده خشک نمونه‌ها نداشت. همچنین با افزایش درصد عصاره جو دوسر، میزان اسیدیته و ماده خشک ماست افزایش و pH نمونه‌ها کاهش معنی‌دار ($p<0.01$) یافت. به علاوه، با گذشت زمان نگهداری، pH و آب‌اندازی کاهش و اسیدیته افزایش قابل توجهی یافت ($p<0.001$) درحالی که همانند آنزیم متغیر زمان تأثیر معنی‌داری بر ماده خشک ماست نداشت. نتایج حسی نشان داد که برخلاف آنزیم ترانس‌گلوتامیناز، افزایش درصد عصارهٔ جو دوسر سبب کاهش امتیاز پذیرش‌کلی محصول شد، اما اختلاف معنی‌داری از این نظر میان نمونه شاهد با نمونه‌های ماست حاوی ۱۰ و ۲۰ درصد عصارهٔ جو مشاهده نشد. بنابراین باتوجه به نتایج این تحقیق، به منظور تولید ماست فراسودمند تیمار آنزیمی ترانس‌گلوتامیناز (۰/۰۲ درصد) و استفاده از ۲۰ درصد عصارهٔ جو دوسر در فرمولاسیون محصول پیشنهاد می‌شود.