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Scientific Research

Investigating the effect of cold plasma on the disinfection and quality of Iranian white cheese during the storage period

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ABSTRACT

Cheese is one of the most consumed milk products. At present, one of the most widely used salty white cheeses in Iran is the cheese produced by the ultrafiltration method. Non-thermal (cold) plasma is a new method to remove food microorganisms. In this research, the effect of cold plasma on the reduction of microbial load and qualitative and rheological characteristics of cheese samples produced through different tests was investigated. The samples were prepared and produced in Pegah Hamadan Company under two microbial treatments (yeast mold and coliform) and the duration of plasma application at two levels (7 and 13 minutes) and the control sample (lack of contamination, no plasma) and during the storage period of 30 days. They were tested once every ten days with 2 repetitions by colorimetric tests, pH, and tissue test (TPA) and Warner test. The results of the statistical analysis of the obtained data showed a significant difference in the evaluated traits between the control sample and the treatments that underwent the cold plasma process. The value of parameter L* in the samples treated with cold plasma decreased compared to the control sample, also the index b* (yellowness index) did not increase significantly for all cheese samples at the end of the storage period. There was no significant difference in the amount of Springiness between the samples treated with plasma and the control sample, and the amount of gumminess did not increase significantly during the storage period (except for the 10th day). There was a significant increase in shear modulus, shear stress and shear force between the first day and the 10th, 20th, and 30th days. It can also be concluded that the treatments with coliform contamination have less stiffness and strength than other treatments and the type pollution added to the samples is the cause of this significant difference.

1. Introduction

Cheese is a dairy product that is obtained after coagulation of milk protein and cheese juice. Approximately one third of the milk produced in the world is used for cheese production [1]. Ultra-refined white cheese is one of the most consumed types of cheese in Iran and it is produced by the ultrafiltration method of pasteurized cow's milk (72 degrees Celsius, 15 seconds) with five times more concentration and the addition of mesophilic lactic starter bacteria specific to cheese. [2]. Dairy products are contaminated by microorganisms, including molds, during the stages of production, supply and storage due to non-observance of hygiene principles. Molds are microorganisms resistant to acid and cold environments and can grow in any foodstuff. Dairy products are acidic due to their low acidity, and molds have the ability to grow in these conditions [3]. In the case of long-term storage of dairy products, the importance of studying fungi becomes more apparent [4]. One of the signs of mold is a change in organoleptic characteristics (color, taste, and smell). There is a possibility of suffering from various types of cancers and hormonal imbalance in case of consumption of this type of food products [3]. The issue of ensuring healthy and quality food has become more complicated today than ever before. Changes in the characteristics of existing microorganisms, changes in production methods, changes in the environment and ecology, and the increase in the amount of food in world trade have caused new risks [5]. With changing consumer needs and issues related to food safety, food processing technologies have also changed to ensure the safety of food products [6]. In addition, there are many other issues related to the quality of thermally processed foods, such as the loss of nutritional quality and adverse effects on organoleptic properties, which lead to the necessity of using non-thermal technologies. [7] Cold plasma technology is one of the new technologies for quality control of food, which creates wide applications, especially in different parts of food processing. Cold plasma has positive effects on the microbial disinfection of various food products to ensure the safety and shelf life of food for consumers [8]. The conducted studies confirm the potential of cold plasma to inactivate harmful microorganisms in milk and dairy products. In dairy products, the antimicrobial efficiency of cold plasma technology depends on various factors, such as target microorganism species, input power, duration of treatment (plasma application), gas composition and food product compositions. The results show that cold plasma can be a good alternative to traditional methods of thermal pasteurization of food in the future, because color changes (browning) and creation of tasteless flavors and loss of nutritional value brings to a minimum [9]. Although many studies have focused on the disinfection ability of cold plasma technology, there is limited research on the effect of cold plasma on food products themselves, especially dairy products [10]. Yang et al. (2015) used cold plasma to disinfect Escherichia coli, Salmonella typhimurium, and Listeria monocytogenes on shredded cheddar cheese with a DBD device at a voltage of 250 V and a frequency of 15 kHz, and the result showed that the population of all three pathogens, respectively it decreased in 60 seconds, 45 seconds and 7 minutes [11]. A study was conducted on the use of cold plasma to sterilize milk at a voltage of 3 kV for 3 minutes at a frequency of 500 Hz, the results showed that plasma is very effective in destroying bacteria in raw milk [12]. In this research, an attempt has been made to reduce the risks to health by examining the effect of cold plasma on the disinfection and quality characteristics of Iranian white cheese while maintaining the nutritional quality of this widely consumed product. So far, many chemical, sensory and microbial tests have been conducted on cheese in food industry, but limited studies have been conducted on cheese by used of mechanical and colorimetric tests, and therefore the findings of these tests can be useful in studying product quality.

2-Materials and methods

Rennet enzyme (cheese liquid)

The enzyme used for retinitis coagulation was Fromas ® TL granulate 2200, which is obtained from the mold Rhizomucor Miehei (DSM Food Specialties, Seclin, France). The storage temperature of this enzyme is between 4 and 8 degrees Celsius and it is used in powder form. Its consumption amount is 2 grams per 100 kg

of retentite, which is added to retentite a few hours before production.

Cheese starter

Starter refers to microbial cultures that are usually used to create special characteristics in milk products as a starting material in order to help coagulation of milk, clot formation, production of flavoring compounds, production of proteolytic enzymes, Lipolytic and reducing pH to an acceptable level the quality of cheese and its ripening are added to milk. The specifications of the starter used in this research were as follows:

RST-744, Mesophilic/thermophilic Culture Blend, Freeze-dried Lactic Culture for Direct Vat Set (DVS). CHR HANSEN.

The forming bacteria were: (Lactococcus lactis subsp. Lactis) and (Lactococcus lactis subsp. Cremoris). All the necessary raw materials for the production of cheese, milk and refining equipment were provided by Pegah Pasteurized Milk Factory in Hamedan.

Method of preparation of test treatments

To produce cheese, 4 kg of pasteurized condensed milk was removed from the production line and cooled to 35°C. The milk used for the project was obtained from the milk used for cheese production in the Pegah factory in Hamedan. To produce cheese samples, 12 ml of starter mixture and cheese rennet were added to condensed milk. The resulting mixture was subjected to two microbial treatments (yeast mold and coliform) and the duration of cold plasma application at two levels (7 and 13 minutes) and the control sample (no pollution, no cold plasma) and after the process, it was packed in 400 gram containers, then placed in a 35°C incubator. The produced cheeses were kept at a temperature of (28-30) degrees Celsius for 24 hours. The specifications of the prepared treatments are shown in Table 1.

Table 1- Specifications of the prepared treatments

Variable name	Type of contamination	Time of use plasma (min)
Control	-	-
Coliform 7	Coliform contamination	7
Coliform13	Coliform contamination	13
Yeast 7	Yeast mold contamination	7
Yeast 13	Yeast mold contamination	13

Test method

For all the tests, the cheese samples were taken out of the laboratory refrigerator, which was set at 7 degrees Celsius, and placed in the laboratory environment with a constant temperature 22 degrees Celsius before the start of the experiment. All the samples were cut in the form of square cubes with dimensions of 20 x 20 x 20 mm. The qualitative indices, textural characteristics and color indices of these treatments were measured during the 30-day storage period and once every 10 days on the first, tenth, twentieth and thirtieth days. All tests were performed in three repetitions.

Plasma generator

In this research, the cold plasma production device was of the dielectric barrier discharge (DBD) type, which had the ability to work at atmospheric pressure, and the gas used for it was air gas. This device was designed and built by the Department of Biosystem Engineering, Faculty of Agriculture, Bu-Ali Sina University (Figure 1). The maximum power and voltage for this device was 30 watts and 16 volts, respectively, and the generated current was 1 amp, and the maximum frequency of the device was 12 kHz. The power source of this device is DC pulse type. In DC pulse sources, pulse power is the accumulation of energy after a relatively long period of time and the release of energy very quickly, which is done in order to increase the instantaneous power of the system.

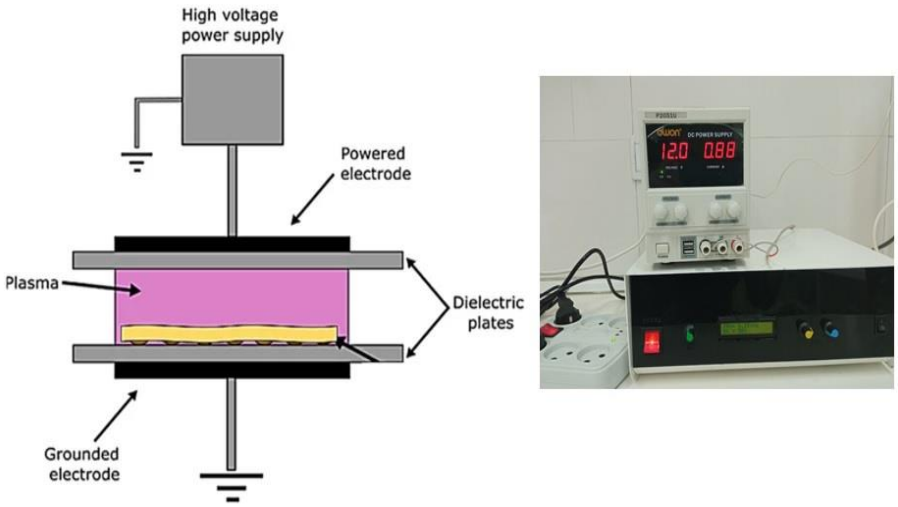

Figure 1- Cold plasmagenerator

Colorimetry test

The colorimetric test was performed using a Hunter lab colorimeter, model HP, made in China. To perform the test, the device was first calibrated with standard plates. The color changes of control and plasma treated cheese samples during the storage period were evaluated by measuring the brightness index L* (black-white) and b* index (blue-yellow). The colorimetric test was performed in three repetitions.

pH measurement

The pH of the samples was measured using pH meter model 766 which was calibrated by buffers 4 and 7.

Tissue Profile Analysis (TPA)

The TPA test was performed by Zwick/Roell BT1 _FR0.5TH.D14 material testing machine with a 500 Newton load cell made in Germany. treatments were performed at a constant speed of 50 mm/min. The amount of preload was 0.1 newton with a speed of 200 mm/min. In this test, the sample is compressed to a certain amount and is subjected to the same force for 15 seconds; then, the moving jaw goes to the level of reduced force determined for the return movement and puts the sample under this force

This test is done with a pressure probe. In each cycle, the sample was compressed until reaching a certain force, then the sample was subjected to the same force for a certain time. The amount of this force was determined by trial and error so that it is at the threshold of the breaking force of the samples.

The test was done for all treatments in 3 cycles and with repetition. All 3 cycles and all 3 back and forth movements for all

for 5 seconds. After 5 seconds, the first cycle is over and the same steps are repeated for the next cycles. Textural parameters such as springiness, Gumminess, Chewiness and Cohesiveness were extracted in the form of force-displacement curves by Test Xpert specialized software.

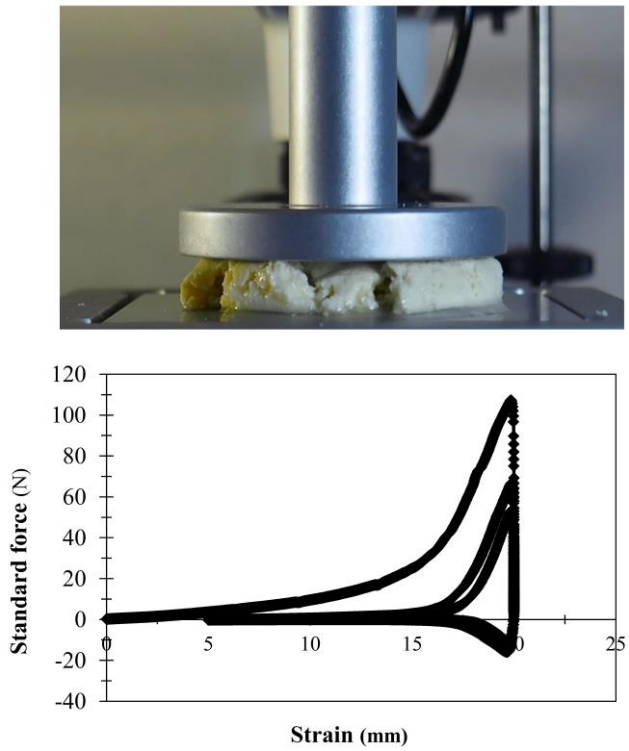

Figure 2- Material Texture Machine, textural parameters test, An example of the force-strain diagram of the this test performed on the specimens

Warner-Bratzler test

The Warner test is one of the food cutting tests in which a stainless steel blade is installed and cuts the product at a constant speed applied by the moving jaw [13]. Werner-Bratzler cutting test was performed by zwick/Roell BT1 _FR0.5TH.D14 material testing machine with 500 Newton load cell made in Germany. The working method was that a cube-shaped piece of cheese with dimensions (2x2x2) was placed in the desired place for cutting, and then a pre-force of 0.1 newton and an initial speed of 100 mm/min were defined. The upper jaw cut the samples at a speed of 50 mm/min after reaching the predetermined pre-force, and at the same time, the stress diagram was drawn according to the shear deformation by the device software. The maximum stress, and the shear modulus, shear stress and shear force parameters were analyzed.

Statistical method of results analysis

After normalization, the data obtained from the experiment were statistically analyzed using factorial test based on completely random design by SPSS version 22 software. Comparison of treatment means was also done with Duncan's multi-range test at the 5% level, and EXCEL2016 software was used to draw graphs.

3-Results and discussion

Colorimetric test results

The results of variance analysis of L* and b* parameters are presented in Table 2. According to the results of analysis of variance given in Table 2, it can be seen that the interaction effect of day × treatment is significant for the L* parameter at the 1% statistical level and for the b* parameter at the 5% statistical level.

Table 2-Variance analysis of color properties (L*, b*) and pH

Variations sources	Degrees of freedom	L*	b*	pH
Treatments	4	26.340^{**}	3.677^{**}	0.004^{**}
Day	3	17.584^{**}	1.308^{ns}	0.005^{**}
Variable*Day	12	4.415^{*}	2.780^{*}	0.001^{**}

Error	20	0.421	1.008	0.000

Notes: * Significant at $p \leq 0.05$, ** Significant at $p \leq 0.01$, and ns not significant.

Figure 2 shows the results of comparing the average day x treatment interaction effect on L* parameter. The highest value of the light factor is related to the control treatment on the first day (98/105) and the lowest value is related to the coliform 7 treatment on the 30th day (90/09). On the first day, a significant difference was observed between the control treatments with coliform 7, yeast 7 and yeast 13. There was a significant difference between the treatments of coliform 7 and coliform 13 on the first and tenth days. On the 20th day, there was a significant difference between the control treatment and coliform 7, coliform 13 and yeast 13 treatments. On the 30th day, no significant difference was observed between the treatments of coliform 7 and coliform 13. However, a significant difference was observed between the control treatment and coliform 7, coliform 13 and yeast 7 treatments. Figure 2 shows the results of comparing the average day x treatment interaction effect on b* parameter. No significant difference was observed between the treatments on the first day. There was a significant difference between the treatments of coliform 13 and control with yeast 7 and coliform 7 on the 10th day. On the 20th day, there was a significant difference between the treatment of coliform 13 and yeast 7. On the 30th day, there was a significant difference between the control treatment with coliform 7 and yeast 7. The results showed that the value of parameter L* in the samples treated with cold plasma decreased compared to the control sample, but the value of parameter b* increased in the treated samples (except coliform 13 and yeast 13 treatment) compared to the control sample. . In a research, the evaluation of a dielectric barrier discharge system to inactivate pathogenic agents on cheese slices was investigated and it was observed that the value of L* parameter in cheese slices decreased after applying cold plasma for 10 and 15 minutes. But the value of b* parameter is increased in samples treated with cold plasma [14].

pH test results

According to the results of analysis of variance given in Table 2, it can be seen that the interaction effect of day × treatment for pH parameter is significant at the statistical level of 1%.

The results of comparing the average day x treatment interaction effect on the pH parameter showed that there is a significant difference of 1% between the control treatment on the first day and the other treatments on the first to 30th days (Figure 2), as the control treatment On the first day (5.190) and yeast treatment 7 on the thirtieth day (4.455) they have the highest and lowest pH values, respectively. However, no statistically significant difference was observed between different treatments on the 10th, 20th and 30th days. Also, the main effect of time on the pH parameter indicates that there is a significant difference at the statistical level of 1% between the first day and the 10th, 20th, and 30th days, and the pH value decreases during the storage period from the first day to the 30th day. It is meaningful. The comparison results of the average main effect of the treatment type on the pH parameter showed that the pH value of the samples treated with cold plasma decreased compared to the control sample, which was consistent with the results of Jung et al. (2015). In a research titled pathogen inactivation and quality changes in cheddar cheese using cold dielectric barrier discharge plasma, they reported that the pH and L* values of cheddar cheese samples by being exposed to dielectric barrier discharge cold plasma for a period of time 10 minutes, decreased [11].

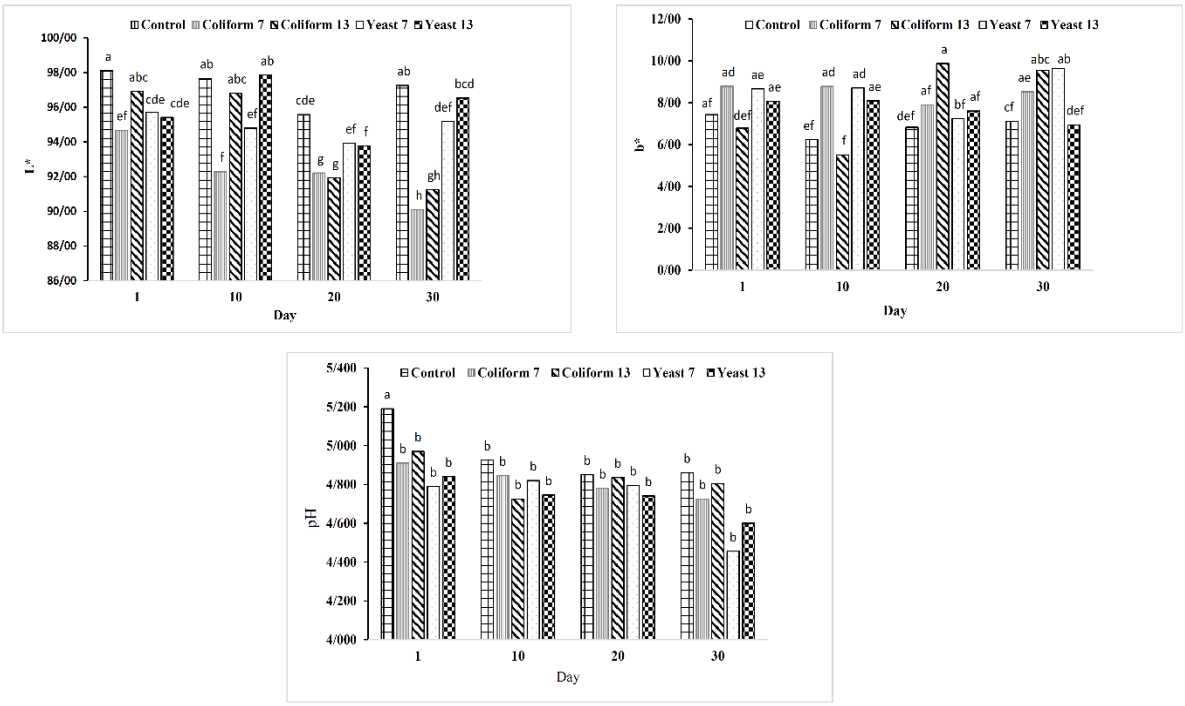

Figure 2- The change of (L^*), (b^*) and pH during storage. Similar letters mean no significant difference

TPA test results

According to the variance analysis results given in Table 3, it can be seen that the interaction effect of day × treatment for Gumminess and Cohesiveness parameters is at a statistical level of 1%, Springiness is at a statistical level of 5%, and there is no significant difference for the Chewiness parameter.

Table 3- Variance analysis of texture properties (Springiness, Gumminess, Chewiness and Cohesiveness)

Variations sources	Degrees of freedom	Springiness (N)	Gumminess (N)	Chewiness (N)	Cohesiveness (N)
Treatments	4	0.072^{**}	0.910^{**}	0.129^{**}	0.002^{**}
Day	3	0.015^{ns}	0.446^{*}	0.028^{ns}	0.003^{**}
Variable*Day	12	0.027^{*}	0.493^{**}	0.020^{ns}	0.001^{**}
Error	20	0.009	0.129	0.009	0.000

Notes: * Significant at $p \leq 0.05$, ** Significant at $p \leq 0.01$, and ns not significant.

Springiness

Springiness refers to the height to which the food is recovered during the period between the end of the first bite and the beginning of the second bite, and it indicates the rate at which a deformed material returns to its normal state after the deformation force is removed. It returns to its original [15]. According to the results of analysis of variance given in Table 3, it can be seen that the main effect of the type of treatment on the Springiness parameter is statistically significant at the 1% level. Figure 3 shows the comparison results of the average interaction effect of day x treatment on the coherence parameter. The maximum amount of Springiness related to yeast treatment is 13 on

the tenth day (0.979 mm) and the minimum amount related to coliform treatment is 7 on the 20th day (0.193 mm). Control treatments, coliform 7 and yeast 13 on the first, tenth, twentieth and thirtieth days do not have significant differences with each other at the statistical level of 5%, also yeast 7 and yeast 13 treatments have significant differences with each other on the first and tenth days.

Gumminess

Gumminess is defined as the energy required to break down a semi-solid food until it is ready to be swallowed [16]. The results of the analysis of variance in Table 3 showed that the main effect of the type of treatment and day on the Gumminess of the samples is significant at the statistical level of 1% and 5%, respectively. Figure 3 shows the results of comparing the average interaction effect of day x treatment on Gumminess parameter. The Gumminess of the samples was in the range of 2.730-0.230 N. Control treatments, coliform 7, coliform 13 and yeast 13 on the first, tenth, twentieth and thirtieth days have no significant difference with each other at the 1% statistical level, but yeast treatment 7 on the tenth day has a significant difference with other treatments. At the statistical level, it is 1%.

Chewiness

Chewiness or solubility is a property in food based on which the chewability of the texture is determined, and having this texture property for food indicates resistance to crushing during chewing [17]. The results of analysis of variance presented in Table 3 show the non-significance of the main effect of day on Chewiness parameters. Figure 3 shows the comparison results of the average interaction effect of day x treatment on Chewiness parameter. The highest Chewiness value is related to the treatment of yeast 7 on the tenth day (0.660 N) and the lowest value is related to the treatment of coliform 7 on the 20th day (0.052 N). On the first day, no significant difference was observed between different treatments. On the tenth day, a significant difference was observed between yeast 7 and control, coliform 7 and coliform 13 treatments. On the 20th day, there was a significant difference between the treatment of yeast 13 and coliform 7, and the control treatments, coliform 13 and yeast 7 did not differ significantly from each other on the 20th day. No significant difference was observed between different treatments on the 30th day.

Cohesiveness

Cohesiveness shows the internal resistance of food structures and means the ability to stay together with the compounds of a product [18]. As the results of analysis of variance in table 3 showed, the main effect of treatment type and day on Cohesiveness parameter is statistically significant at 1% level. Figure 3 shows the comparison results of the average interaction effect of day x treatment on the Cohesiveness parameter. On the first day, a significant difference was observed between the control treatment and the other treatments at the statistical level of 1%, but no significant difference was observed among the other treatments during the maintenance period. The general trend of changes shows a decrease in the amount of Cohesiveness of different treatments during the storage period.

By comparing the average effect of the type of treatment on the Springiness parameter in Table 4, it can be seen that there is no significant difference at the 1% statistical level between the control treatment and the treatments that were subjected to cold plasma (except yeast treatment 13). Also, the results of the comparison of the average effect of the type of treatment on the Springiness parameter showed that among the similar treatments, the treatments that were subjected to cold plasma for 13 minutes had a higher amount of Springiness than the treatments that were subjected to plasma for 7 minutes. The comparison results of the average effect of time on the Springiness parameter in Table 5 showed that the amount of Springiness was constant during the storage period and no significant difference was observed between different days. So it can be concluded that cold plasma did not have a negative effect on the elasticity of the treatments during the storage period. Lobato-Calleros et al. (2008) reported that fresh cheese proteins are highly cross-linked in a 3D network and show high resistance to deformation, meaning that the cheese is more elastic [19].

The results of the comparison of the average main effect of the type of treatment on the viscosity parameter in Table 4 showed that there is no significant difference between the control treatment and other treatments (except yeast treatment 7). And according to table 5, the

gum content increased from the first to the tenth day and decreased from the tenth to the thirtieth day. The results of the comparison of the average effect of time on chewiness parameter in Table 5 showed that since viscosity has a direct relationship with chewiness according to the formula, their changes during the storage period were completely similar to each other. The results were consistent with the results of Rashidi et al. (2015) [20]. In a research titled "Improving the texture and sensory properties of ultra-refined low-fat feta cheese made with fat substitutes, they came to the conclusion that by adding whey protein concentrate to the milk used for cheese production, the chewiness and gumminess of the cheese decreased."
In the examination of the main effect of time on the value of cohesion parameter in Table 5, it was observed that there was a significant decrease in its value during the storage period between the first day and other days, but its value was constant from the tenth day to the thirtieth day and the significant decrease did not have Protein and fat are continuously broken down during the ripening process. Casein is first hydrolyzed into long-chain peptides, which are subsequently degraded into short-chain peptides. Some caseins are finally broken down into amino acids and volatile substances. After dispersing into small fat globules, large fat globules are further broken down into ketones, aldehydes and lactones, which are broken down into volatile substances and free fatty acids. Hydrolysis of components in cheese caused the viscosity to increase gradually during the ripening process and the cohesion to decrease gradually [21].

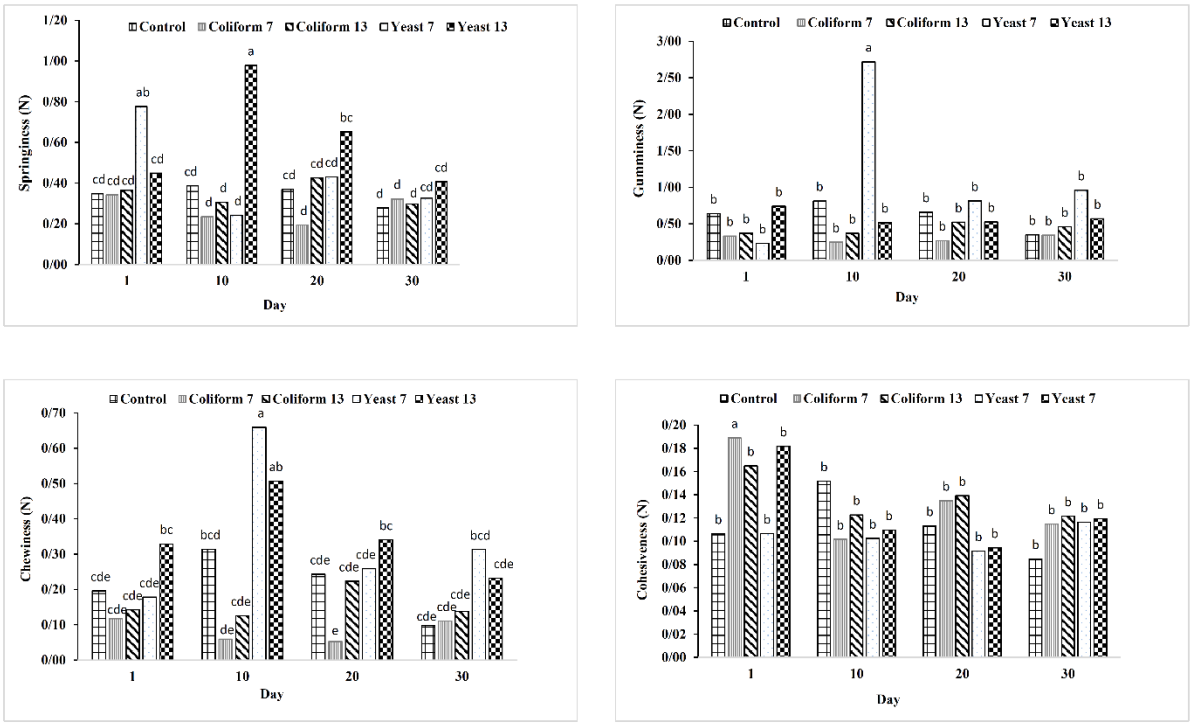

Figure 3- The change of springiness, gumminess, chewiness and cohesiveness during storage. Similar letters mean no significant difference

Table 4- The results of comparing the average effect of treatment type on the parameters of springiness, gumminess, chewiness and cohesiveness

Treatments	Springiness (N)	Gumminess (N)	Chewiness (N)	Cohesiveness (N)

Control	0.346^{bc}	0.16^{b}	0.212^{b}	0.113^{bc}
Coliform 7	0.273^{c}	0.299^{b}	0.085^{c}	0.135^{a}
Coliform 13	0.349^{bc}	0.430^{b}	0.157^{bc}	0.137^{a}
Yeast 7	0.444^{b}	1.182^{a}	0.352^{a}	0.104^{c}
Yeast 13	0.622^{a}	0.588^{b}	0.352^{a}	0.126^{ab}

Similar letters mean no significant difference

Table 5- The results of comparing the average effect of treatment time on the parameters of springiness, gumminess, chewiness and cohesiveness

Day	Springiness (N)	Gumminess (N)	Chewiness (N)	Cohesiveness (N)
1	0.456^{a}	0.436^{b}	0.192^{b}	0.150^{a}
10	0.430^{a}	0.933^{a}	0.333^{a}	0.118^{b}
20	0.414^{a}	0.558^{b}	0.223^{b}	0.115^{b}
30	0.326^{a}	0.536^{a}	0.178^{b}	0.111^{b}

Similar letters mean no significant difference

Warner test results

The results of variance analysis of parameters of shear modulus, shear stress and shear force are presented in Table 6. According to the variance analysis results, it can be seen that the interaction effect of day × treatment has a significant difference for shear stress and shear force parameters at the statistical level of 1% and for the shear modulus parameter at the statistical level of 5%.

Shear modulus

Shear modulus expresses the resistance and how the material reacts to shearing. The shear modulus is widely used to show the relationship between stress and strain in solid and semi-solid food materials, the higher the shear modulus, the higher the stiffness of the material texture and its resistance to shear forces [22]. According to the results obtained in Table 6, the main effect of treatment type and the main effect of time are significant at the 1% probability level on the value of shear modulus. Figure 4 shows the results of comparing the average day x treatment interaction effect on shear modulus parameter. The trend of changes in shear modulus shows that the highest value of shear modulus is related to yeast treatment 7 on the 20th day (0.189 kPa) and the lowest value is related to coliform 7 treatment on the 30th day (0.135 kPa). On the first day, there was no significant difference at the 5% statistical level among the different treatments. There is a significant statistical difference of 5% between the control treatments and coliform 7 on the 10th day, as well as the coliform 7 treatments with yeast 13 on the 30th day, and also between the yeast 7 treatment on the 20th day and the other treatments on the first days. There is a significant difference in the tenth, twentieth and thirtieth.

Table 6- Variance analysis of shear modulus, shear stress and shear force

Variations sources	Degrees of freedom	Shear modulus (k.pa)	Shear stress (k.pa)	Shear force (N)

Treatments	4	0.119**	1.318**	0.196**
Day	3	0.104**	1.076**	0.170**
Variable*Day	12	0.050*	0.383**	0.063**
Error	20	0.017	0.136	0.024

Notes: * Significant at $p \leq 0.05$, ** Significant at $p \leq 0.01$, and ns not significant.

Shear stress

Considering that the stress is obtained by dividing the force on the cross-sectional area under shear, therefore, the process of changes in shear stress is completely consistent with the changes in shear force. Figure 4 shows the comparison results of the average interaction effect of day x treatment on the shear stress parameter. Among the treatments of coliform 13 with yeast 13 on the first day, yeast 7 with coliform 7 treatments, coliform 13 and yeast 13 on the 20th day, there is a significant difference at the statistical level of 1%, also between the control treatment on the 20th day and coliform 7 treatments, coliform 13 on the same day and the treatment of yeast 13 with coliform 13 and coliform 7 on the 30th day, there is a statistically significant difference at the 1% level. The highest shear stress related to yeast treatment 13 on the 30th day was 2.465 kPa.

Shear force

According to the results of analysis of variance in Table 8-3, the main effect of treatment type and time was significant at the 1% probability level on shear force. Figure 4 shows the comparison results of the average interaction effect of day x treatment on shear force parameter. The maximum amount of shear force related to the treatment of yeast 13 on the 30th day (9.86 newtons) and the minimum value related to the treatment of coliform 13 on the first day (1.2 newtons) and among the treatments of coliform 13 and coliform 7 on No significant difference was observed during the maintenance period. There is a statistically significant difference of 1% between the treatments of yeast 7 with the treatments of coliform 7, coliform 13 and yeast 13 on the 10th day, also there is a statistically significant difference between the control treatment on the 20th day and the treatments of coliform 7 and coliform 13 on the same day. Dar is present at the level of 1%. On the 30th day, a significant difference at the statistical level of 1% was observed between the control treatments with coliform 7 and coliform 13.

By comparing the average main effect of the treatment type on the shear modulus parameter in Table 7, it was observed that the control treatment with coliform 7 and yeast 7 treatments has a significant difference at the statistical level of 1%. Regarding the shear stress parameter, the control treatment with coliform 7 and coliform 13 treatments has a significant difference at the statistical level of 1%. But there is no significant difference with yeast 7 and yeast 13 treatments. According to Table 7 and Table 8, as it is clear, the trend of changes in shear force in terms of the effects of type of treatment and time is completely similar to the changes in shear stress. In this context, Madsen and Ardo (2001) by studying the sensory and rheological properties of Danbo cheese stated that the shear stress at the breaking point has a direct relationship with the hardness of the cheese and the higher this stress is, the greater the hardness and strength, and vice versa with decreasing It makes the cheese lose its consistency [23]. So it can be concluded that treatments with coliform contamination have less stiffness and strength than other treatments and the type of contamination added to the samples is the cause of this significant difference. Regarding the effect of time, according to Table 8, it is clear that the values of all 3 shear parameters increased from the first day to the thirtieth day. Georgala et al. (2005), in their study on feta cheese, stated the reason for this issue as follows: in the early ripening period, the ratio of coagulant activity to proteolytic activity is higher and therefore leads to an increase in dry matter, because the higher the coagulating power, the more watery and watery, the dry matter of the cheese increases and the rind becomes firmer [24].

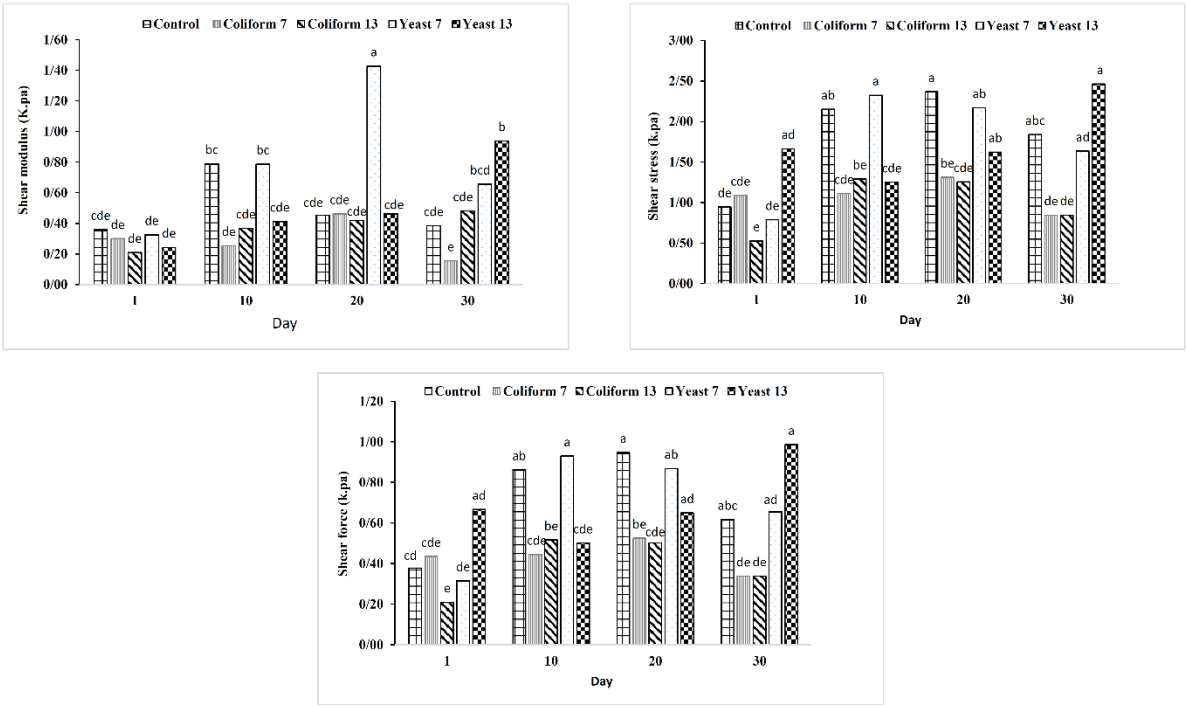

Figure 4- The change of shear modulus, shear stress and shear force during storage. Similar letters mean no significant difference

Table 7- The results of comparing the average effect of treatment time on the parameters of shear modulus, shear stress and shear force

Treatments	Shear modulus (k.pa)	Shear stress (k.pa)	Shear force (k.N)
Control	0.497[b]	1.827[a]	0.701[a]
Coliform 7	0.293[c]	1.089[b]	0.436[b]
Coliform 13	0.369[bc]	0.980[b]	0.392[b]
Yeast 7	0.799[a]	1.730[a]	0.692[a]
Yeast 13	0.514[b]	1.751[a]	0.701[a]

Similar letters mean no significant difference

Table 8- The results of comparing the average effect of treatment type on the parameters of shear modulus, shear stress and shear force

Day	Shear modulus (k.pa)	Shear stress (k.pa)	Shear force (k.N)
1	0.287[b]	1.002[b]	0.401[b]

10	0.522[a]	1.627[a]	0.651[a]
20	0.645[a]	1.746[a]	0.699[a]
30	0.523[a]	1.526[a]	0.587[a]

Similar letters mean no significant difference

4- Conclusion

The results of the color indexes of the cheese samples during the storage period showed that the L* index (brightness index) for the samples treated with cold plasma and the control sample had a significant difference and the value of the L* parameter in the sample treated with cold plasma decreased compared to the control sample, also the b* index (yellowness index) for all cheese samples did not increase significantly at the end of the storage period and the results showed that the samples that were applied for 7 minutes The cold plasma had a significant difference with the control sample and the value of b* parameter increased in the treated samples (except coliform 13 and yeast 13 treatment) compared to the control sample. The results of the pH test showed a significant difference between the samples treated with plasma and the control sample, so that its value for the treated samples decreased significantly compared to the control sample during the storage period. Such an increase in the duration of plasma application did not have a significant effect between the samples infected with yeast mold and coliform. According to the results of the TPA test, the amount of Springiness did not decrease significantly between the different treatments during the storage period, and no significant difference was observed between the samples treated with plasma and the control sample. The application of cold plasma did not create a significant difference between the control sample and the treated samples (except for yeast 7) and the gum content did not increase significantly during the storage period (except for the 10th day). From the first day to the 30th, the cohesion value had a significant decrease between the control sample and the samples treated with cold plasma. The results of Warner's test showed that, in general, there was a significant increase in shear modulus, shear stress and shear force between the first day and the 10th, 20th, and 30th days. The maintenance was similar to changes in stress and shear force.

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مقاله علمی_پژوهشی

بررسی اثر پلاسمای سرد بر میکروب‌زدایی وکیفیت پنیر سفید ایرانی در طول دوره نگهداری

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چکیده

پنیر از پرمصرف‌ترین فرآورده‌های شیر است. در حال حاضر یکی از پرمصرف‌ترین پنیرهای سفید نمکی در ایران پنیر تولیدی به روش اولترا فیلتراسیون (Ultrafiltration) است. پلاسمای غیر حرارتی (سرد) یک روش نوین جهت حذف میکروارگانیسم‌های مواد غذایی می‌باشد. در این پژوهش اثر پلاسمای سرد بر کاهش بار میکروبی و ویژگی‌های کیفی و رئولوژیکی نمونه‌های پنیر تولیده شده از طریق آزمون‌های تجربی بررسی گردید. نمونه‌ها در شرکت پگاه همدان تحت دو تیمار میکروبی (کپک مخمر و کلیفرم) و مدت اعمال پلاسما در دو سطح (۷ و ۱۳ دقیقه) و نمونه شاهد (فاقدآلودگی، فاقد پلاسما) تهیه و تولید شدند و طی دوره نگهداری ۳۰ روزه هر ده روز یک‌بار با ۲ تکرار توسط آزمون‌های رنگ-سنجی، pH، آزمون بافت (TPA) و تست وارنر مورد آزمایش قرار گرفتند. نتایج حاصل از تجزیه و تحلیل آماری داده‌های بدست آمده، تفاوت معنی داری را در صفات مورد ارزیابی بین نمونه شاهد و تیمارهایی که تحت فرآیند با پلاسمای سرد قرار گرفتند نشان داد. مقدار پارامتر L^* در نمونه‌های تیمار شده با پلاسمای سرد نسبت به نمونه شاهد کاهش یافت، همچنین شاخص b^* (شاخص زردی) برای همه‌ی نمونه های پنیر در پایان دوره نگهداری افزایش معنی‌دار نداشت. مقدار فنریت بین نمونه‌های تیمار شده با پلاسما و نمونه شاهد اختلاف معنی‌دار مشاهده نشد، همچنین مقدار صمغیت در طول دوره نگهداری (به جز روز دهم) افزایش معنی‌دار نداشت. مقدار مدول برشی، تنش برشی و نیروی برشی بین روز اول با روزهای دهم، بیستم و سی‌ام افزایش معنی‌دار وجود داشت، همچنین می‌توان نتیجه گرفت که تیمارهای دارای آلودگی کلیفرم سفتی و استحکام کمتری نسبت به سایر تیمارها دارند و نوع آلودگی اضافه شده به نمونه‌ها عامل ایجاد این تفاوت معنی‌دار است.