Original Article

The Effect of Biodegradable PLA Packaging on The Quality of Cream Cheese During Modified Atmospheric Storage

Khadijeh Mahinkheil*, Mahsa Tabari, Rahim Rahebi

Food Science Department, Food Industry, Faculty of Marine Science and Technology, Azad Islamic University, North Tehran, Iran.

Abstract

In this study, the effect of packages made of Poly-Lactic Acid (PLA) on cream cheese was analyzed and compared with poly-propylene (PP) in similar packaging and preservation. Eight 100-gram packages made of PLA, designed and manufactured by a 3D printer along with four 100-gram packages made of PP, were filled and packed with cream cheese in sterile conditions at Pakban Company, and incubated at 4 and 25 °C for 45 days. At 15-day intervals, pH, acidity, moisture loss, texture, color, and sensory properties were tested in all the eight packages at identical conditions. Results showed a further decrease in pH values and an elevation in the acidity with increasing storage time. A further reduction of moisture loss was also observed at both refrigerated and ambient temperatures. The PLA and PP packages were not significantly different in terms of moisture loss at refrigerated temperature within the 45-day storage conditions hence the PLA is not problematic for cheese packaging. In this study, the cream cheese sample packaged in PLA and stored at 4 °C was found as the best sample compared to those stored at 25 °C by maintaining the desired organoleptic properties similar to the control treatment with no significant difference.

Keywords: Poly-lactic Acid, poly-propylene, packaging, cheese, physicochemical properties, sensory properties

INTRODUCTION

Today, polymers and materials used in food packaging include a wide variety of polymers dependent on petroleum compounds, metals, paper, and wood, or compounds of these materials. Durability and degradability of packaging materials are two contrasting issues, the former being suitable for packaging durability and protection during the product shelf life, and the latter is in fact its rapid environmental degradation [1]. Nowadays, packages are mainly made of polyolefine (pp), polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC), etc., all of which are provided from fossil fuel sources [2]. Challenges and concerns about the degradability and decomposition of a polymer in the natural environment include changes in the chemical structure, reduction of structural and mechanical properties, and ultimately transformation into the natural environment such as water, carbon dioxide, minerals, and intermediate products such as biomass and organic matter. The natural environment includes chemical, biological, and physical forces with environmental factors such as temperature, moisture, pH, the presence of oxygen, and so on, which determine the rates and products of a biodegradable process [2]. Biodegradable polymers are those whose chains in the environment are degraded by microorganisms. Such conditions as pH, moisture, oxygen content, and the presence of some metals are highly effective in the biological degradation rate of these polymers [3]. Biodegradable polymers fall into two main groups. The first group consists of those made of natural renewable sources, such as polylactic acid (PLA), polyhydroxybutyrate (PHB) and its copolymers, starch, cellulose, gelatin, chitosan, and so on. The second group comprises those fabricated from petroleum sources including biodegradable aliphatic polyesters (BAPs), polybutylene succinate (PBS), polycaprolactone (PCL) and polyvinyl alcohol (PVA). Biodegradable polymers made from natural renewable sources have recently attracted a lot of interests due to their economic and ecological attractions [3]. The biodegradability of these materials, reduction of accumulated waste volume, fertilizer ability in the natural cycle, reduction

Address for correspondence: Mrs. Khadijeh Mahinkheil, Food Science Department, Food Industry, Faculty of Marine Science and Technology, Azad Islamic University, North Tehran, Iran.

How to cite this article: Mahinkheil, Kh., Tabari, M., Rahebi, R. The effect of biodegradable PLA packaging on the quality of cream cheese during modified atmospheric storage. Arch Pharma Pract 2020;11(S1):148-56.

of CO2 levels and the possibility of using agricultural resources for producing biodegradable polymers are some of the factors making this scientific and industrial attractiveness for such materials [4]. PLA is a low molecular weight chiral polymer containing an asymmetric carbon atom with a helical structure. It is also a greasy compound with heat flexibility that is easily biodegraded through enzymatic and hydrolytic pathways. This compound was discovered by Carothers by vacuum-heating of lactic acid [5], and has such advantages as biodegradability, biocompatibility, good processability, and energy storage.

Packaging is one of the most sensitive and crucial stages of supply and consumption of goods that can be a distinguishing factor from competitors and some kind of competitive advantage. Since packaging is the last step in the food processing, it is one of the critical and effective factors in product quality. Improper packaging can damage the taste and nutritional quality of packaged foods [6]. The aim of food packaging is to increase the food shelf life, reduce waste volume, and transport foods better and easier [7].

Studies conducted on the production of PLA include a review on the PLA production from biomass [8], a study on biopolymer-based films (PLA) [9], effect of biodegradable packaging and modified atmosphere on food with short and medium shelf life [4], production of biodegradable packaging films based on polylactic acid biopolymer in combination with chitosan and silver nanoparticles [10], and the effect of PLA on the quality of semi-hard cheese during storage in dark and light using oxygen scavengers [11].

PLA has high potential to replace industrial polymers and be applied in a variety of industries, in particular packaging. There has been scarce research on the use of PLA in food packaging. In this study, therefore, the effect of PLA, as one of the polyester materials used in food packaging, on the quality of cream cheese during light and dark storage period.

Materials And Method

Production and packaging of cream cheese in PLA packaging PLA cheese packages of 100 g were designed and manufactured in Arka Pioneers of Technology Company by a 3D model design using the 3D Modeling (CATIA) software. The designed model of 100-g cheese packaging was then produced with PLA raw materials by a 3D printer. The PLA container was 300 microns thick and 120 cm3 wide, with a headspace volume of 70 ml. The 100-g container of cheese packaging was made of polypropylene, a product of a company producing plastic containers. Six 100-g PLA containers and six similar 100-g containers made of PP with cream cheese molds (100 g cream cheese with an average fat of ≈ 30%) were manufactured by the Paksan Company under sterile and controlled conditions of filling and packing cheese. The packages were refrigerated at 4 °C and 40% humidity under the same conditions as shops and retailers. Half of the packages are covered with black plastic to protect them from light. Samples were regularly rotated so that there was no difference between them in terms of exposure to temperature and light.

Mold and Yeast Tests

Molds and yeasts of cheese samples were counted based on the method (No. 10154) of the National Standard of Iran. To this end, 1 g of the sample with 3 cc of sterile normal saline was homogenized in a sterilized mortar (123 °C for 1 h) during 63 sec followed by preparation of 1 dilution per plate of YGC culture. The desired dilution (1 cc) was incubated on the plate surface containing YGC culture medium at 25 °C for 9 days. The molds and yeasts were counted after incubation (Iranian National Standard, 10154).

pH test

The pH of cheese samples was measured during cold storage at 15-day intervals for 45 days. To measure pH, 10 g of cheese sample was mixed with 90 g of deionized water. The prepared mixture was then passed through a coarse filter paper (medium Whatman 150 mm). Finally, pH was measured using a digital pH meter [12].

Moisture test

The cheese moisture was tested according to the Iranian national standard (No. 1753). To do this test, a container (25 mm H and 70 mm D) made of stainless steel was heated in a ventilated oven and adjustable at 2 ± 102 °C for 2 h. The lid was placed on the container (containing sand and stirrer rod) and immediately transferred to a desiccator to cool down at room temperature for 45 min. The container was then weighed together with the rod, sand, and lid with an accuracy of 0.1 mg. The prepared container was slightly tilted to collect the sand on one side, about 3 g of the prepared sample was placed in its empty side, and the lid was placed. The container was then shaken with the stirrer rod and weighed to the nearest 0.1 mg. The sample was thoroughly mixed with sand to spread uniformly inside the container using the wide end of the stirrer and then rod was leaned against the container wall. The stirrer rod was placed upright inside the container with the lid lying alongside was heated in an oven for 3 h, and then the lid was placed on the container and immediately transferred to a desiccator. The container was cooled to room temperature for at least 45 min and then weighed to the nearest 0.1 mg. The container was placed in the oven and reheated for 1.5 h. After this time, the lid was placed on the container and immediately transferred to the desiccator. The container was then weighed at room temperature for at least 45 min to the nearest 0.1 mg, and the operation was repeated until the difference between the two consecutive weights was not more than 0.5 g, with recording the lowest weight.

Acidity

Acidity was measured according to Marshall [13]. About 3.5 g of pure sample was weighed in a 250 ml Erlenmeyer flask, about 75 ml of distilled water was added, and stirred well to completely dissolve the sample. After adding six drops of phenolphthalein reagent, the Erlenmeyer content were titrated with 0.1 N standardized hydroxide solution. The acidity was expressed in milligrams of potassium hydroxide per gram of the sample using the following formula [13].

AV (mg KOH) = NaOH (ml) × 0.01× 56.1/g

Colorimetry of cheese samples with the Hunter system

Samples were placed in special packaging bags at 4 °C. The color colorimetry test was performed using a colorimeter at a viewing angle of 10° and a hole diameter of 25 mm. Data from this device include a* (redness, red = positive numbers, green = negative numbers), b*(yellowish, yellow = positive numbers, blue = negative numbers), and L* (shining, white = 0, black = 100).

Texture

The hardness, adhesiveness, elasticity, gumminess, and chewiness of cheese texture samples were measured using a texture analysis apparatus with 50 kg loading cell, a diameter of 13 mm, penetration rate of 150 mm/s into the sample, and a penetration depth of 10 mm [12].

Sensory evaluation (color, taste, odor, texture, and overall acceptance)

According to the table of National Standard of Iran (No. 695) and by the method of Koca and Metin [14] by five trained assessors based on the 5-point hedonic scale during storage at 4 °C on 0, 15, 30, and 45 days.

Statistical analysis

This study was conducted in a completely randomized design with three replications. Data were analyzed using SAS software version 9. Mean values were compared by Duncan's multiple range test. The charts were drawn using Excel software.

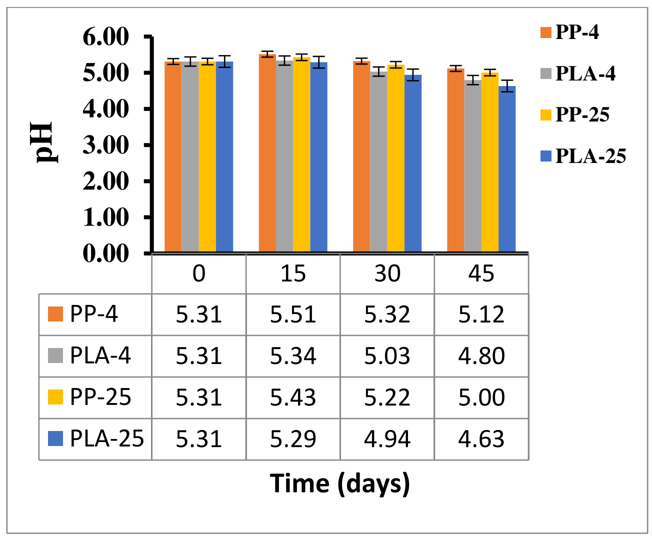
Results

Results from pH, acidity, and moisture of cream cheese samples packed in PLA during storage at 4 and 25 °C

Based on the statistical results (Table 1 and Figure 1), the pH values of cheese samples are significantly different in different treatments ($p < 0.01$). Also, statistically significant differences are observed between the pH levels of cheese samples during 45 days of storage at 15-day intervals ($p < 0.01$). The interaction of the variables is very significant on the pH of cheese samples ($p < 0.01$). According to Table 1 and Figure 3, the moisture content of cheese samples has a statistically significant difference in different treatments ($p < 0.01$). There are also statistically significant differences between the moisture contents of cheese samples during 45 days of storage at 15-day intervals ($p < 0.01$). The interaction of the variables is statistically significant on the moisture content of cheese samples ($p < 0.01$).

Table 1: ANOVA results for pH, acidity, and moisture content of cream cheese samples packaged in PLA during storage at 4 and 25 °C

Variable	S.O.V	df	SS	MS	F	Sig.
pH	Treatment	3	0.5324	0.1775	1.45052E-32	<.0001
	Time	3	1.7991	0.5997	5.58704E-41	<.0001
	Treatment × Time	9	0.2439	0.0271	1.45917E-24	<.0001
	Error	32	0.0050	0.0002		
	Total	47	2.5804			
Acidity	Treatment	3	0.0281	0.0094	0.008	<.0001
	Time	3	2.4850	0.8283	0.009	<.0001
	Treatment × Time	9	0.0097	0.0011	0.03	<.0001
	Error	32	0.0008	0.0000		
	Total	47	2.5237			
Moisture	Treatment	3	17.561	5.854	0.000	<.0001
	Time	3	20.530	6.843	0.000	<.0001
	Treatment × Time	9	11.769	1.308	0.000	<.0001
	Error	32	0.461	0.014		
	Total	47	50.321			



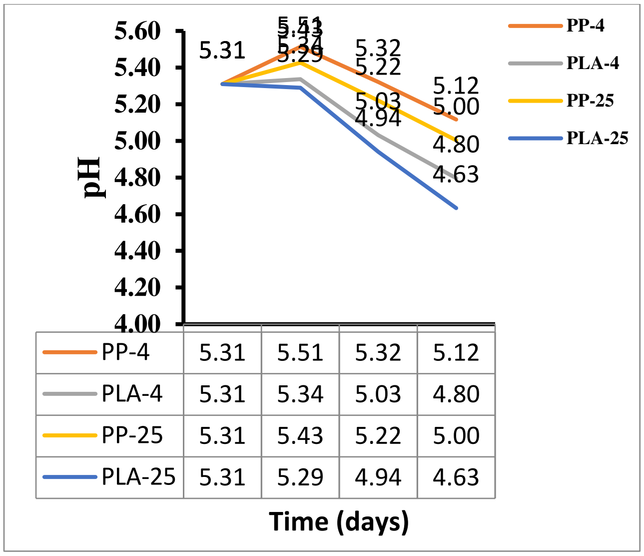


Figure 1: pH changes in cream cheese packaged in PLA during storage at 4 and 25 °C

Figure 2 shows the acidity changes of cream cheese packaged in PLA during storage at 4 and 25 °C

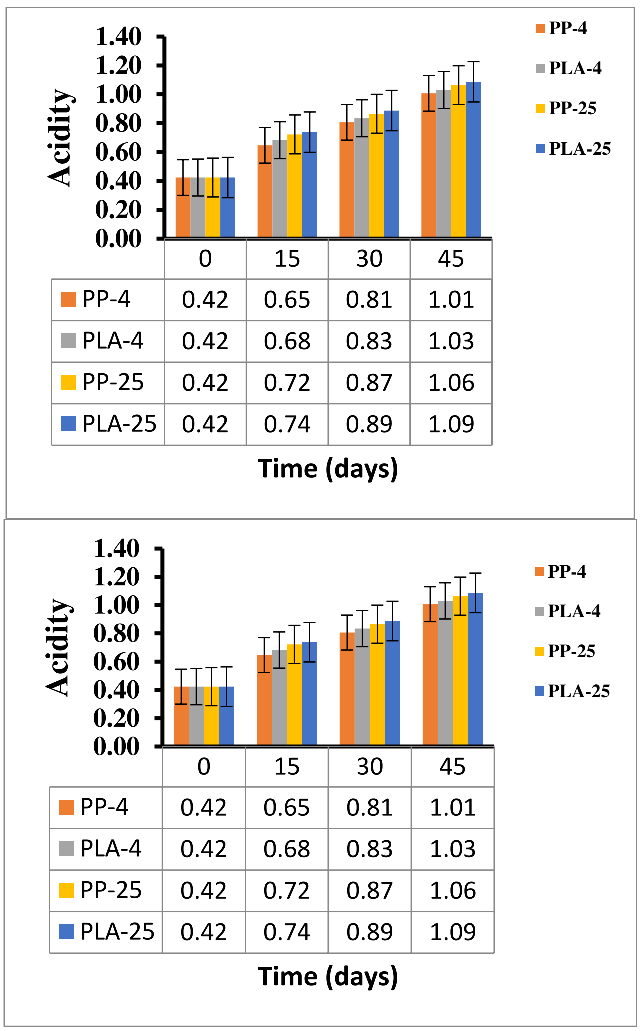


Figure 2: Acidity changes in cream cheese packaged in PLA during storage at 4 and 25 °C

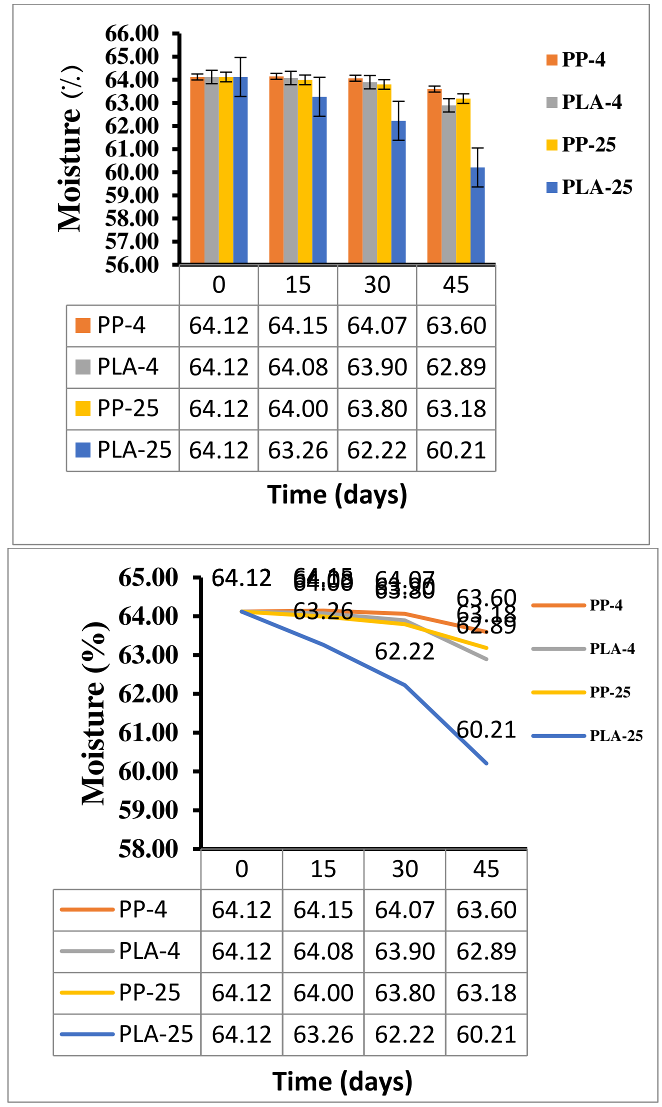


Figure 3: Moisture changes in cream cheese packaged in PLA during storage at 4 and 25 °C

Results of color [whiteness (L*), redness (a), and yellowish (b*)] in cream cheese samples packed in PLA during storage at 4 and 25 °C

Based on statistical results (Table 2 and Figure 4), the amount of whiteness (L*) in cheese samples was not significantly different in different treatments ($p > 0.01$). Also, there are statistically significant differences between the white colors of cheese samples during 45 days of storage at 15-day intervals ($p < 0.05$). The interaction of the variables on the white color of cheese samples is not statistically significant ($p > 0.05$). According to Table 2 and Figure 5, the redness (a*) of cheese samples did not have statistically significant differences in different treatments ($p < 0.01$). Also, cheese samples were not significantly different in terms of redness during 45 days of storage at 15-day intervals ($p < 0.01$). The interaction of the variables on the redness of cheese samples is not statistically significant ($p < 0.01$). As shown in Table 2 and Figure 6, the yellowness (b*) of cheese samples was significantly different in different treatments ($p < 0.01$). Cheese samples were significantly different in terms of yellowness during 45 days of storage at 15-day intervals ($p > 0.05$). The interaction of the variables is statistically significant on the yellowness of cheese samples ($p > 0.05$).

Table 2: ANOVA results for whiteness (L*), redness (a), and yellowness (b*) levels of cream cheese packaged in PLA during storage at 4 and 25 °C

Variable	S.O.V	df	SS	MS	F	Sig.
Whiteness (L*)	Treatment	3	0.80	0.267	0.895	>.0001
	Time	1	9.37	9.375	0.018	<.05
	Treatment × Time	3	0.96	0.321	0.868	>.0001
	Error	16	21.44	1.340		
	Total	23	32.58			
Redness (a)	Treatment	3	1.440	0.480	0.958	>.0001
	Time	1	0.158	0.158	0.857	>.0001
	Treatment × Time	3	1.440	0.480	0.958	>.0001
	Error	16	75.880	4.743		
	Total	23	78.919			
Yellowness (b*)	Treatment	3	1.806	0.602	0.882	>.0001
	Time	1	0.774	0.774	0.603	>.0001
	Treatment × Time	3	1.806	0.602	0.882	>.0001
	Error	16	43.961	2.748		
	Total	23	48.347			

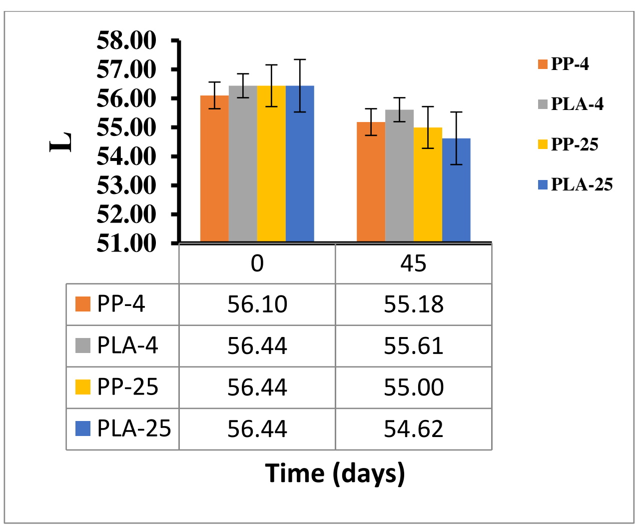


Figure 4: Changes in the whiteness (L*) of cream cheese samples packaged in PLA during storage at temperatures of 4 and 25 °C

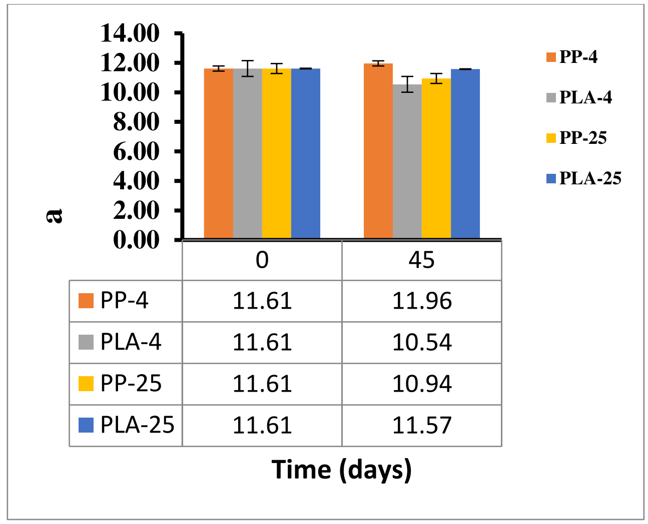


Figure 5: Changes in redness (a) of cream cheese samples packaged in PLA during storage at 4 and 25 °C

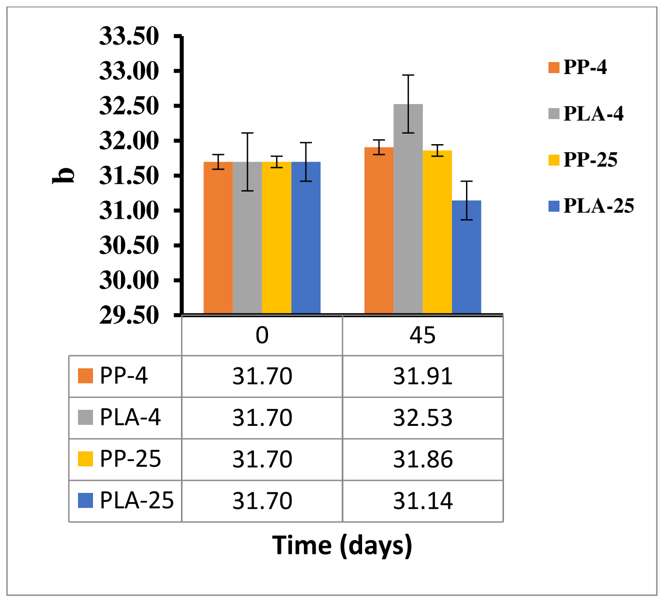


Figure 6: Changes in yellowness (b*) of cream cheese samples packaged in PLA during storage at 4 and 25 °C

Results of mold and yeast counts in cream cheese samples packaged in PLA during storage at 4 and 25 °C

Based on statistical results (Table 3 and Figure 7), cream cheese samples in different treatments are significantly different in terms of Lactobacillus acidophilus viability ($p < 0.01$). Also, statistically significant differences are observed between the mold and yeast counts in cream cheese samples stored at 25 °C during 45 days at 15-day intervals ($p < 0.01$). The interaction of the variables is statistically significant on mold and yeast counts in cream cheese samples ($p < 0.01$).

Table 3: ANOVA results for mold and yeast counts in cream cheese packages packaged in PLA during storage at 4 and 25 °C

S.O.V	df	SS	MS	F	Sig.
Treatment	3	236.73	78.91	0.0000	<.0001
Time	3	410.06	136.69	0.0000	<.0001
Treatment × Time	9	710.19	78.91	0.0000	<.0001
Error	32	229.33	7.17		
Total	47	1586.31			

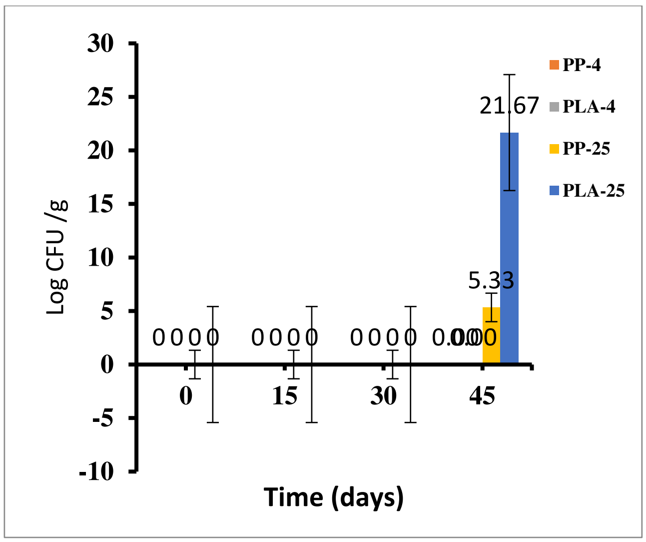


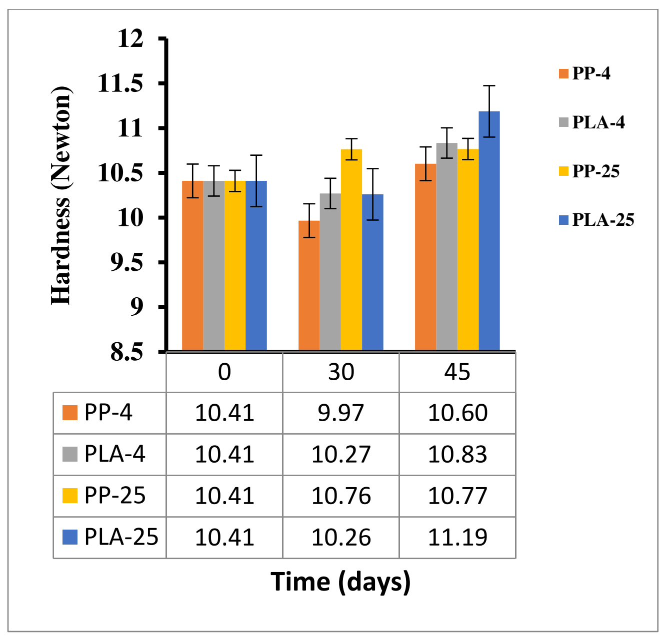
Figure 7: Changes in mold and yeast counts in samples of cream cheese packaged in PLA during storage at 4 and 25 °C

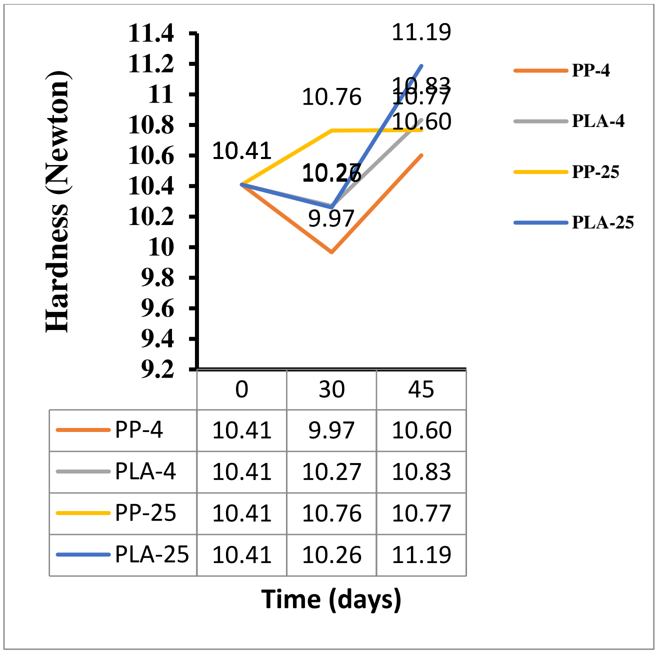
Results of texture analysis (hardness, cohesiveness, elasticity, gumminess, and chewiness)

According to statistical results, levels of hardness, cohesiveness, elasticity, gumminess, and chewiness of cheese samples are not significantly different in different treatments ($p < 0.01$). Also, there is no significant statistical difference between the hardness of cheese samples during 45 days of storage at 15-day intervals ($p < 0.01$). The interaction of the variables is not statistically significant on the hardness of cheese samples ($p < 0.01$) (Table 4 and Figures 8-12, respectively).

Table 4: ANOVA results for hardness, cohesiveness, elasticity, gumminess, and chewiness of texture in cream cheese samples packaged in PLA during storage at 4 and 25 °C

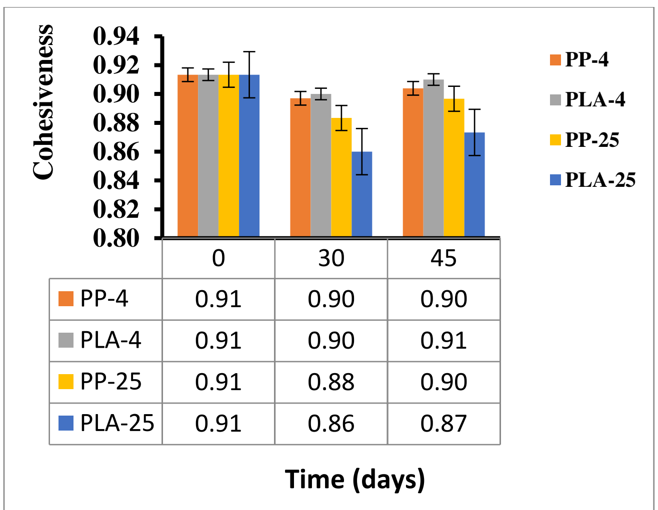
Variable	S.O.V	df	SS	MS	F	Sig.
Hardness	Treatment	3	0.572	0.191	0.136	>.0001
	Time	3	1.933	0.966	0.689	>.0001
	Treatment × Time	9	0.956	0.159	0.114	>.0001
	Error	32	33.668	1.403		
	Total	47	37.129			
Cohesiveness	Treatment	3	0.01	0.002	1.077	>.0001
	Time	3	0.01	0.003	1.991	>.0001
	Treatment × Time	9	0.01	0.001	0.513	>.0001
	Error	32	0.04	0.002		
	Total	47	0.06			
Elasticity	Treatment	3	0.041	0.014	2.604	>.0001
	Time	3	0.002	0.001	0.231	>.0001
	Treatment × Time	9	0.022	0.004	0.681	>.0001
	Error	32	0.127	0.005		
	Total	47	0.193			
Gumminess	Treatment	3	0.19	0.063	0.030	>.0001
	Time	3	0.67	0.337	0.161	>.0001
	Treatment × Time	9	1.78	0.296	0.142	>.0001
	Error	32	50.09	2.087		
	Total	47	52.73			
Chewiness	Treatment	3	3.82	1.273	0.451	>.0001
	Time	3	1.24	0.622	0.220	>.0001
	Treatment × Time	9	4.71	0.785	0.278	>.0001
	Error	32	67.79	2.824		
	Total	47	77.55			



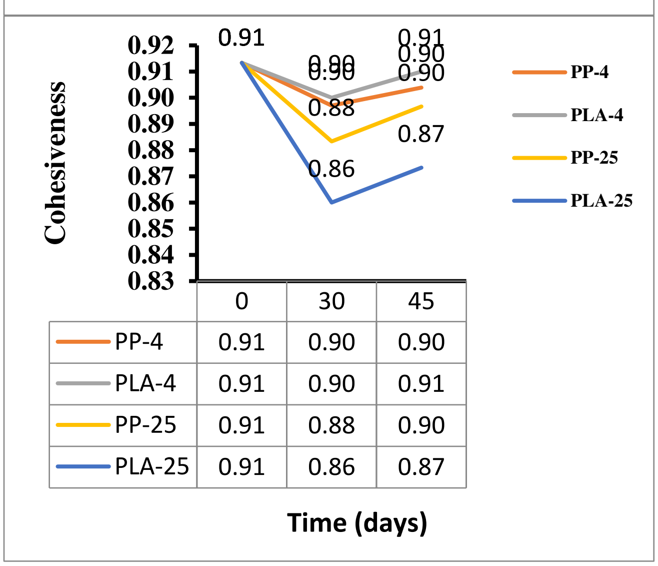


	0	30	45
PP-4	10.41	9.97	10.60
PLA-4	10.41	10.27	10.83
PP-25	10.41	10.76	10.77
PLA-25	10.41	10.26	11.19

Figure 8: Changes in the texture hardness of cream cheese packaged in PLA during storage at 4 and 25 °C

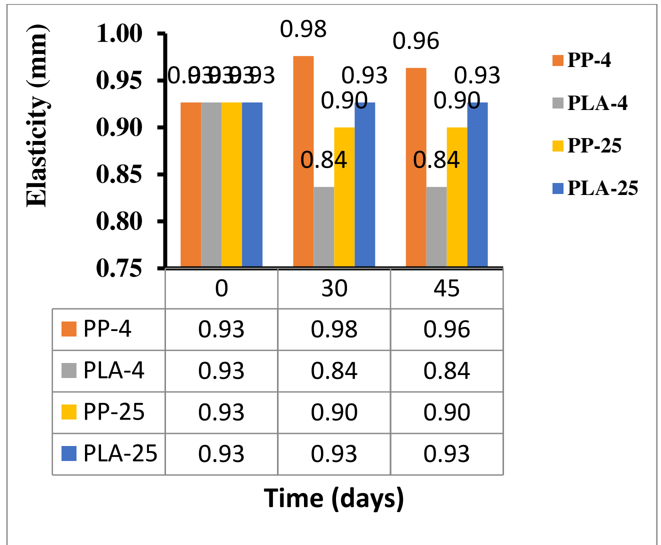


	0	30	45
PP-4	0.91	0.90	0.90
PLA-4	0.91	0.90	0.91
PP-25	0.91	0.88	0.90
PLA-25	0.91	0.86	0.87

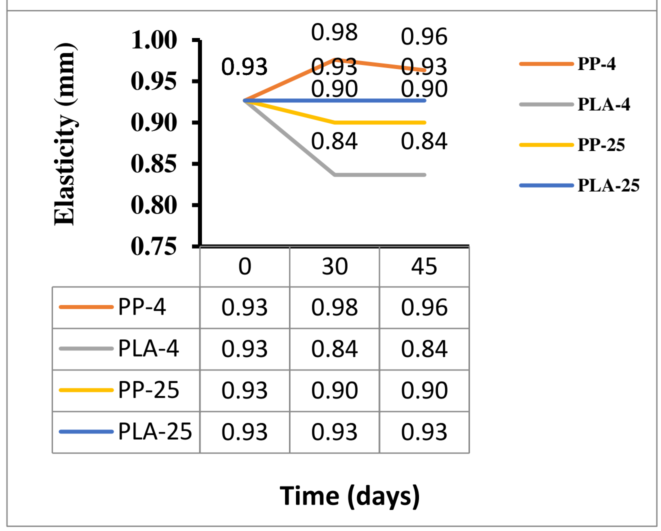


	0	30	45
PP-4	0.91	0.90	0.90
PLA-4	0.91	0.90	0.91
PP-25	0.91	0.88	0.90
PLA-25	0.91	0.86	0.87

Figure 9: Changes in the texture cohesiveness of cream cheese packages packaged in PLA during storage at 4 and 25 °C

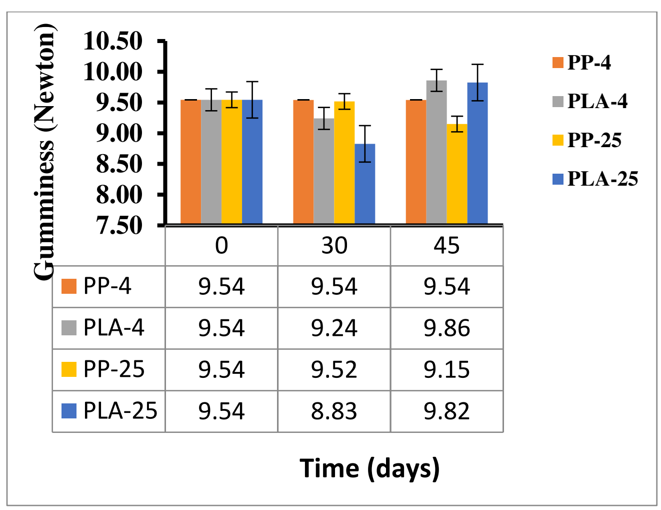


	0	30	45
PP-4	0.93	0.98	0.96
PLA-4	0.93	0.84	0.84
PP-25	0.93	0.90	0.90
PLA-25	0.93	0.93	0.93



	0	30	45
PP-4	0.93	0.98	0.96
PLA-4	0.93	0.84	0.84
PP-25	0.93	0.90	0.90
PLA-25	0.93	0.93	0.93

Figure 10: Changes in texture elasticity of cream cheese packaged in PLA during storage at 4 and 25 °C



	0	30	45
PP-4	9.54	9.54	9.54
PLA-4	9.54	9.24	9.86
PP-25	9.54	9.52	9.15
PLA-25	9.54	8.83	9.82

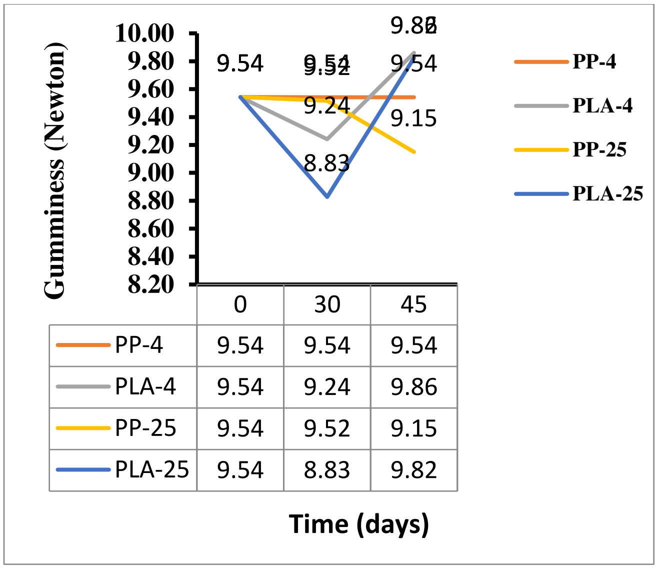


Figure 11: Changes in the texture gumminess of cream cheese samples packaged in PLA during storage at 4 and 25 °C

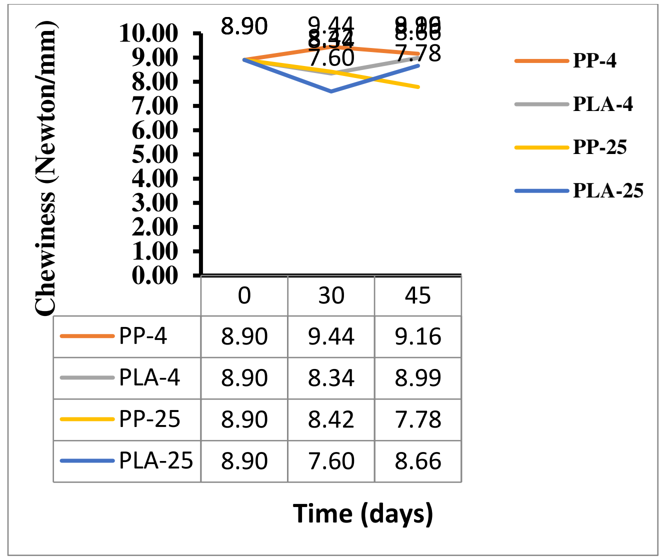
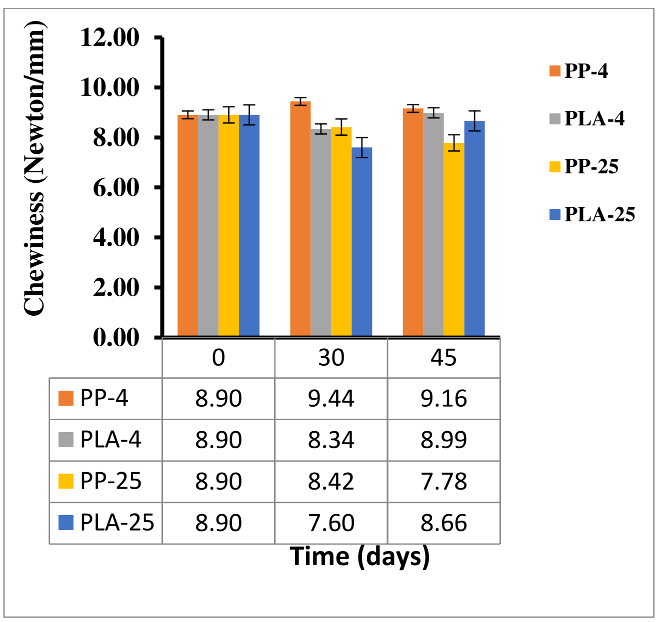


Figure 12: Changes in the texture chewiness of cream cheese samples packaged in PLA during storage at 4 and 25 °C



The effect of research variables on sensory properties (color, taste, odor, texture, and overall acceptance) of cream cheese samples packaged in PLA stored at 4 and 25 °C

Based on the statistical results of color, taste, odor, texture, and overall acceptance of cheese samples in different treatments, there are no significant differences after 45 days of storage at 4 and 25 °C ($p > 0.05$). Also, the interaction of variables (4 and 25 °C) on the color of cheese samples is not statistically significant ($p > 0.05$) (Table 5).

Table 5: Sensitivity analysis of color, taste, odor, texture and overall acceptance of cream cheese samples packed in PLA stored at 4 and 25 °C

Variable	S.O.V	df	SS	MS	F	Sig.
Color	Treatment	3	0.229	0.076	0.627	>.05
	Error	8	1.000	0.125		
	Total	11	1.229			
Taste	Treatment	3	0.563	0.1875	0.441	>.05
	Error	8	1.5	0.1875		
	Total	11	2.063	0.1875		
Odor	Treatment	3	0.729	0.243	0.297	>.05
	Error	8	1.333	0.167		
	Total	11	2.063	0.188		
Texture	Treatment	3	1.896	0.632	0.058	>.05
	Error	8	1.333	0.167		
	Total	11	3.229	0.294		
Overall acceptance	Treatment	3	9.750	3.250	0.017	>.05
	Error	8	4.167	0.521		
	Total	11	13.917	1.265		

Discussion And Conclusion

According to the statistical results, the acidity of cheese samples is significantly different in different treatments ($p < 0.01$). Also, there are statistically significant differences between the acidity of cheese samples during 45 days of storage at 15-day intervals ($p < 0.01$). The interaction of the variables is statistically significant on the acidity of cheese samples ($p < 0.01$). Values of pH in cheese samples packaged in PLA and control samples (pp-25 and PLA-25) decreased significantly during 45 days of storage at ambient temperature ($p < 0.01$). However, no significant decreases in pH occurred in cheese samples packaged in PLA and control samples (pp-4, PLA-4) during refrigerated storage. However, the acidity of cheese samples packaged in PLA and control samples (pp-25 and PLA-25) increased significantly during 45 days of storage ($p < 0.01$). However, the increased acidity in cheese samples packaged in PLA and control samples (pp-4, PLA-4) was not statistically significant during storage at refrigerator temperature. The results indicate that increasing time led to a further decrease in the pH and an increase in the acidity. After 45 days of storage at 25 °C, the lowest pH was related to the cheese sample stored in the PLA package, which decreased from 4.63 to 4.23. Also, the highest amount of acidity was produced in the cheese sample stored in the PLA package, which declined from 0.42 to 1.09 after 45 days of storage at 25 °C. The decrease in pH caused by increased acidity can be attributed to the activity of microorganisms such as mold and yeast. These results are similar to those of Dukalska et al. [15] who observed a reduction of pH due to the effect of PLA packaging in the storage of Kleo soft cheese. Our results revealed further moisture reductions with increasing time in all treatments at refrigerated and ambient temperatures. Moisture reduction in cheese samples packaged in PLA and control samples (pp-4 and PLA-4) was not statistically significant during refrigerated storage. Moisture in cheese samples packaged in PLA and control samples (pp-25 and PLA-25) decreased significantly during 45 days of storage at ambient temperature ($p < 0.01$). The lowest moisture content was recorded in the cheese sample stored in the PLA package, which decreased from 5.31 to 4.23 after 45 days of storage at 25 °C. The difference in moisture loss of cheeses packaged in PLA and PP containers during the 45-day storage results from the higher moisture loss of PLA containers due to the plant-derived nature, which is similar to moisture loss results of Holm et al. [11]. The non-significant difference in moisture loss of PLA and PP containers during storage for 45 days at refrigerated temperature may lead to the conclusion that there is not much difference between moisture loss in PLA and PP containers at refrigerated temperature; thus, PLA containers in are not problematic for cheese packaging in terms of moisture loss. These results are in line with that of Dukalska et al. [15] who studied of the effect of PLA packaging on the reduction of moisture in the storage of Kleo soft cheese.

The L* index is a dark-light index, the higher and lower levels of which indicate more brightness and darkness, respectively. The results of L* index shows that the storage of cheese samples at 4 °C led to a higher loss of whiteness (L*) than at 25 °C, but this decrease was not statistically significant. This suggests the higher color quality of the PLA-packed cheese, indicating identical whiteness between the cheeses packaged in the PLA and PP vessels stored in similar conditions. Dukalska et al. [15] obtained similar results in the study of PLA packaging effect on the preservation of Kleo soft cheese. The a* is called the redness-greenness index, the higher and lower levels of which indicate more redness and greenness, respectively. The results of this index showed that the degree of redness (a*) increased with rising the storage time of cheese samples. There were no statistically significant differences in redness between the PLA-packaged cheese samples and the control sample at 4 and 25 °C during 45 days ($p < 0.01$). The b* is the yellowness-blueness index, the higher and lower levels of which represent yellowness and blueness, respectively. The results showed that the degree of yellowness (b*) was lower in the control cheese (pp) than the PLA treatment. The difference in the yellowness level between the cheese samples packaged in PLA and the control sample was not statistically significant at 4 and 25 °C during 45 days ($p < 0.01$).

From a sensory viewpoint, hardness is the force required to compress a sample between grinding teeth, and it is mechanically the force required to achieve an obvious transformation [16,17]. Our observations demonstrate that the hardness increased with rising time in all treatments stored at refrigerated and ambient temperatures. The increased hardness of PLA-packaged and control (pp-4 and PLA-4) cheese samples was not statistically significant during storage at refrigerated and ambient temperatures. The effects of packaging and temperature variables had a small effect on the hardness during 45 days of storage, which was higher at ambient than the refrigerated temperature of storage conditions. However, the observed difference for the hardness of cheese samples was not statistically significant between the treatments. These results are similar to that of Dukalska et al. [15] who reported an increase in the hardness of Kleo soft cheese stored in PLA packaging. Also, Rashidi et al. (2011) studied the effect of cheese fat replacement and obtained similar results.

Cohesiveness indicates the level of transformation that occurs in a sample when it is compressed by grinding teeth before rupture and is strongly dependent on the internal links making up the product body [16,17]. Based on the present results, the cohesiveness decreased by increasing the time in all treatments stored at refrigerated and ambient temperatures. The packaging and temperature variables did not have significant effects on the cohesiveness of the cheese samples. Besides, the observed changes between treatments revealed that the cheeses stored in PLA packaging had greater cohesiveness than the control treatment under the same refrigerated and ambient temperatures during 45 days of storage, but the treatments were not statistically different in this respect. This is attributed to the weakness of internal bonds in the structure of cheeses with higher moisture and softer texture, as a result of which the cheese is easily and irreversibly deformed under pressure by a texture analyzer Zisu et al. (2005). These results are similar to that of Koca et al. [14] concerning an increase in the hardness.

From a sensory point of view, elasticity is the degree or intensity by which the sample returns to its original shape and size after a slight pressure between the tongue and the palate;

from a mechanical standpoint, it is the amount of deformation in which a deformed sample returns to its original state the force removal [16,17]. The results showed that the elasticity of cheese samples declined during storage, but the packaging and temperature variables did not have significant effects on the elasticity of cheese samples and the treatments were not different significantly. Even so, the highest amount of elasticity was observed in the PLA packaging treatment with the least amount of moisture content, which corresponds to that of Koca et al. [14] regarding a reduction in the elasticity.

Gumminess is the energy needed to grind a semi-solid food until it is ready for swallowing. Its value is obtained via multiplying the values of hardness by cohesiveness and is expressed in grams or Newton [16,17]. Examination of the results indicated that the gumminess varied in the treatments during the storage period. The cheese samples packaged in PLA and stored in the ambient and the refrigerator conditions contained a higher amount of gumminess than the control treatment, which was not statistically significant. Treatments with more moisture content showed less gumminess [18].
Chewiness is the energy needed to chew a solid food until it is ready for swallowing a certain amount of food. Its numerical value is obtained via multiplying the springiness value by the gumminess [16,17]. The packaging and temperature variables did not have significant impacts on the chewiness of cheese samples, and the treatments did not differ significantly, but the chewiness was uppermost in the treatment with the highest amount of fat and therefore the least amount of water. Koca et al. [14] presented evidence that a decrease in the moisture content of cheese samples led to a decrease in the chewiness, which is in accordance with our results.

Cheese samples were evaluated by eight people at different times. Each individual sample was provided to the assessors at a specific time to reflect their final opinions on the experimental groups in special forms without comparing their opinions with those of others. Individuals' opinions were reported qualitatively in special forms and ranked in terms of texture, odor and flavor, hardness, and color. The results revealed that the quality of cheese samples packaged in PLA and PP containers and stored at 4 °C was not statistically significant in terms of sensory indices. It was, however, better than cheese samples packaged in PP and PLA containers and stored at 25 °C for 45 days, which was statistically significant for the overall acceptance of the sample.

In this study, the effect of PLA packaging was examined on some physicochemical properties (pH, acidity, moisture, color, and texture) and sensory properties (color, taste, odor, texture, and overall acceptance) of cream cheese during 45 days at 4 and 25 °C. According to the results, PLA packaging affected the physicochemical properties of cream cheese. An increase in the time led to a further decrease in pH and an increase in acidity. Moreover, a more reduction of moisture content was onserved with increasing time in all treatments stored at refrigerated and ambient temperatures. However, the difference in moisture loss was not statistically significant between PLA and PP containers during storage for 45 days at refrigerated temperature. It can, therefore, be concluded that PLA and PP containers were not significantly different concerning moisture loss at refrigerated storage temperature and PLA-packaged cheese is not problematic in terms of moisture loss. PLA packaging reduced levels of cheese whiteness (L*) and yellowness (b*), but it had no effect on the redness (a*) index. In this study, the cream cheese sample packaged in PLA and stored at 4 °C was found as the best sample, compared with those stored at 25 °C, by maintaining the desired organoleptic properties similar to the control treatment with no significant difference.

References

1. Bohlmann GM. Biorefinery process economics.2006
2. Siracusa, V., Rocculi, P., Romani, S., Dalla Rosa, M. Biodegradable polymers for food packaging: a review. Trends in Food Science & Technology, 2008; 19(12), 634-643.
3. Ray SS, Bousmina M. Biodegradable polymers and their layered silicate nanocomposites: in greening the 21st century materials world. Progress in materials science. 2005 Nov 1;50(8):962-1079.
4. Peelman N, Ragaert P, Vandemoortele A, Verguldt E, De Meulenaer B, Devlieghere F. Use of biobased materials for modified atmosphere packaging of short and medium shelf-life food products. Innovative Food Science & Emerging Technologies. 2014 Dec 1;26:319-29.
5. Lasprilla AJ, Martinez GA, Lunelli BH, Jardini AL, Maciel Filho R. Poly-lactic acid synthesis for application in biomedical devices—A review. Biotechnology advances. 2012 Jan 1;30(1):321-8.
6. Ramezani R, Karbasi A. The effect of different packaging and lighting conditions on the stability of refined sunflower oil. Journal of Agricultural Science and Technology and Natural Resources, 2002; 6, 2. 139-148.
7. Mir Nazemi Ziabari H. Principles of food packaging. Fourth edition, Aiej Publications. Tehran. 2002.
8. Islahi Nopashani E, Lotfi M, Ghaderi Nasab E, Quchan, Islamic Azad University, Faculty of Chemical Engineering, Department of Chemical Engineering, 2013.
9. Imam Jomeh Z, Dadashi S, Ebrahimzadeh Mousavi SM, Urmiaei A, Karaj, Agricultural and Natural Resources Campus, University of Tehran, Faculty of Agricultural Engineering and Technology, Department of Food Science and Engineering. 2011.
10. Azli NB. Biodegradable Films from Poly (lactic Acid)(PLA)-chitosan-silver Nanoparticles: Preparation and Characterization (Doctoral dissertation, UMP).
11. Holm VK, Mortensen G, Risbo J. Quality changes in semi-hard cheese packaged in a poly (lactic acid) material. Food chemistry. 2006 Aug 1;97(3):401-10.
12. Quds Rouhani M, Mortazavi A, Mazaheri Tehrani M, Razavi MA, The effect of process conditions on chemical and sensory properties of refined processed Feta cheese produced from a mixture of cow's milk and soy milk. Iranian Journal of Food Science and Technology, 2009; 6, 1, 87-98.
13. Marshall R. Standard methods for the examination of dairy productsWashington, DC: American Public Health Association. pp. 450. 2005.
14. Koca N, Metin M. Textural, melting and sensory properties of low-fat fresh kashar cheeses produced by using fat replacers. International dairy journal. 2004 Apr 1;14(4):365-73.
15. Dukalska L, Muizniece-Brasava S, Murniece I, Dabina-Bicka I, Kozlinskis E, Sarvi S. Influence of PLA film packaging on the shelf life of soft cheese Kleo. World Academy of Science, Engineering and Technology. 2011 Aug 23;80:295-301.
16. Fox PF, Guinee TP, Cogan TM, McSweeney PL. Fundamentals of cheese science. Aspen Publishers Inc, USA. 2000.
17. Gunasekaran S, Ak MM. Linear viscoelasticity of cheese. Cheese Rheology and Texture, CRC press; 2002 Dec 23. 215-272.
18. Saint-Eve A, Lauverjat C, Magnan C, Deleris I, Souchon I, Reducing salt and fat content: impact of composition, texture and cognitive

interaction on the perception of flavored model cheeses, Food Chemistry, 2009; 116, 167-175.