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Effects of Aloe vera gel based active coating functionalized with lemon peel essential oil on shelf life and quality attributes of cheese

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Abstract

In this study, the effect of an edible aloe vera gel-coating containing lemon peel essential oil (0, 100, and 150 ppm) on the qualitative characteristics of cheese samples was examined. Treatments included 4 groups: control (without coating), aloe vera gel (AVG), AVG + 100 ppm lemon peel essential oil (EO), and AVG + 150 ppm lemon peel EO. These treatments were evaluated for 60 days in terms of physicochemical, textural, sensory, and microbial counting properties. The findings revealed that as storage duration increased, the acidity and salt increased while pH and moisture content decreased. In evaluating the sensory properties, the effect of treatments on all sensory properties except color scores was significant. Samples coated with AVG and 100 ppm lemon peel EO received the highest flavor scores (4.97). As the storage time increased, the hardness, chewiness and springiness of the cheese samples increased. The samples' adhesiveness was not affected by the storage duration. At the end of the storage time, the highest total microbial, mold and yeast counts were associated with the control cheese samples (5.37 and 4.62 log cfu/g, respectively) and the lowest amount was related to the samples coated with AVG and 150 ppm of lemon peel EO (3.92 and 3.76 log cfu/g, respectively). In general, the use of edible coating produced with AVG and lower concentrations of lemon peel EO (100 ppm and less) improved the appearance and the flavor of cheese samples during 60 days of storage.

Keywords: Aloe vera, Edible coating, Lemon peel essential oil, Cheese, Sensory evaluation, Textural properties.

Introduction

Nowadays, chemical preservatives have been proved to be harmful and consumers are more desired to use foods without preservatives or containing natural preservatives (Sambu *et al.*, 2022). Cheese is a nutrient-dense dairy food, providing protein, fats, and minerals (Yerlikaya and Ozer, 2014). Cheese can be used as a main ingredient in meals, as a dessert and as a component of foods. The rapid growth of cheese consumption in the world particularly in European countries is due to its use in various foods (Gomes da Cruz *et al*., 2009).

Due to its nutrients, cheese provides a favorable environment for the growth of several bacteria. Globally, there are a vast selection of different cheese varieties, and each one has a unique microbiological profile. The high nutritional value of cheese has led to extensive studies to improve the quantitative and qualitative properties of this product and the production of more marketable products (Trmčić *et al*., 2016). Mold growth during the ripening and manufacturing of cheese is one of the common issues faced by cheese makers. This problem is also seen for sellers and consumers of this product during refrigeration. The use of herb materials has been considered for many years to prevent the growth of various microorganisms and molds. (Sengun *et al*., 2008).

Some natural and edible film-forming materials can be used to preserve foods such as cheese. One of these natural ingredients is aloe vera gel (AVG). A clear and firm gel is extracted from the inner parts of the leaves of the aloe vera (*Aloe barbadensis* Miller). AVG is odorless, non-sticky and has a high absorption strength. More than 98% of aloe vera gel is made up of water, followed by polysaccharides (pectin, cellulose, hemicellulose, glucomannan, and acemannan), the acemannan being considered as the main functional component of AVG (Bozzi *et al*., 2007). Aloe vera is also an excellent source of antioxidants, Vitamin C, Vitamin A, Vitamin E, Beta-carotene, Folic acid, Calcium, and Magnesium (Suriati, 2018). Aloe gel has high potential to be used in the food industry, one of which as an edible coating material (Suriati *et al.*, 2020). This gel is a polysaccharide coating and can prevent moisture loss of the product. Due to the presence of different chemicals including aloin, acemannan (Martinez-Romero *et al*., 2018)., anthraquinone, saponins (Ergun and Satici, 2012) and phenolic compounds such as chatechin hydrate, caffeic acid, ferulic acid, ellagic acid, and quercetin (Sumi *et al.*, 2019), AVG has antifungal and antimicrobial characteristics and inhibits the growth and proliferation of fungus.

Essential oils (EO) are another herbal component that can be utilized in edible films and coatings. Citrus peel EO is a mixture of more than 100 compounds, which is divided into two volatile parts (99-85% of the total essential oil), and the non-volatile part (1-15%). The volatile parts include monoterpenes (such as limonene) and sesquiterpene hydrocarbons and oxygenated derivatives [aldehydes (such as citral), ketones and acids (along with linear aldehydes), alcohols (such as linalool)] and esters and the non-volatile parts include hydrocarbons, fatty acids, sterols, carotenoids, waxes, coumarins, and flavonoids (Bennici and Tani, 2004). Limonene is the main monoterpene compound of citrus essential oil and has antioxidant, antibacterial and antiviral properties (Espina *et al*., 2011; Roy *et al*., 2007). In general, Citrus peel EOs have potent antioxidant and antibacterial properties (Raspo *et al.*, 2020).

In a reported study, Shenbagam *et al*. (2023) investigated the effects of aloe vera gel-based edible coating (with or without incorporation of orange peel essential oil) on the postharvest shelf life and qualitative properties of button mushroom. The results showed that maximum concentration of orange peel essential oil (1500 µL/L) incorporated in the 50% aloe vera gel significantly improved the postharvest quality attributes of mushrooms and helped extend the shelf life of mushrooms up to 4 days as compared to the control.

This study's objective was to determine the effect of an edible coating made of AVG and various concentrations of lemon peel EO on physicochemical, sensory and textural properties as well as microbial profile (total microbial count and total mold and yeast counts) of cheese.

Methods

Preparation of lemon peel essential oil

20 kg of Mexican lemon peel (*Citrus aurantifolia*) was dried at an ambient temperature (25-38°C) and in the shade. The dried lemon peel was grounded and passed through a sieve (mesh 40). The EO was extracted by steam distillation over a Clevenger system (Aria Exir, Iran) for 4h. The obtained EO was dehydrated using sodium sulfate and stored at 4°C (Chanthaphon *et al.*, 2018). Lemon peel EO was yellow in color and yield of extracted EOs was 1.1% (w/w).

Preparation of AVG

Aloe vera leaves were collected from University of Jiroft Research Farm. The leaves were washed and their jagged edges were cut with a knife. The top layer of the leaf was removed lengthwise and the gel was carefully separated from the leaf. The gel parts were blended thoroughly and put through a clean metal sieve (mesh 20) to form a homogeneous solution and the extract was finally pasteurized at 65°C for 15 min (Martinez-Romero *et al*., 2018). In this study, Aloe vera extract at a 100% concentration was used.

Coating formulations and application

The cheese samples were prepared in Kerman Pegah milk factory. To produce cheese, milk was pasteurized after fat standardization (3.5%) by HTST method and then concentrated at 50°C in ultra-filtration system until reaching 34% dry matter. Starter inoculation was done at 32-35°C. Then, rennet (12 ml per 400 g) was added and mixed well. The mixture was poured into containers and after passing through the coagulation tunnel (30°C for 20 min), salt (3%) was added. After that, it was sealed and placed in an incubator at 28°C until reaching a pH of 4.7. Then, it was transferred to the cold room and kept at 4°C until the experiments (Khani and Roufegari Nejad, 2018). The cheese samples were cut into cubic specimens ($3 \times 3 \times 3$ cm^3) and coated by immersion method. During this step, the cheese samples were immersed in the coating mixture (AVG with various concentrations of lemon peel EO (0, 100 and 150 ppm which was homogenized by a homogenizer at 1000 rpm) for 1 minute. The samples were incubated for about 8 hours under controlled temperature (12°C) and humidity (relative humidity of 85%) to dry all coatings (Henriques *et al*., 2013). AVG and lemon peel EO created a colorless coating on the samples. The samples were then placed in sealed polypropylene containers and stored in the refrigerator (4°C) and evaluated at 15 days of intervals throughout 60 days of storage period.

Experimental methodology

Determination of acidity

The acidity of cheese samples was determined in terms of lactic acid and by titration with sodium hydroxide (0.1 N) using the equation 1 (Iranian International Standard No2852:1995).

Equation 1: Acidity%= N. 0.009.100/M

In this equation, N is the amount of sodium hydroxide 0.1 N consumed (ml) and M is the weight of the sample.

pH measurement

A digital pH meter (Metrohm, model 827, Switzerland) was used to determine the samples' pH levels (Iranian International Standard No2852:1995).

Measurement of moisture content

Cheese samples were placed in an oven at 102°C until they reached a constant weight (about 5 h). The dried samples were weighed after cooling, and the amount of moisture loss was estimated using the equation 2 (Roy *et al*., 2007):

Equation 2: Moisture loss rate= Weight before drying - Weight after drying / Weight before drying × 100

Measurement of salt content

Mohr method was used to determine the amount of salt. Titration was performed using silver nitrate solution (0.1 N) until an orange precipitate appeared. The percentage of salt was calculated as equation 3 (Dorosti *et al*., 2011).

Equation 3: Amount of salt% = ml of consumed silver nitrate (ml) × silver nitrate N × 0.585

Sensory evaluation

Sensory properties of cheese samples were evaluated using a five-point hedonic test (very bad: 1 to very good: 5) in the first and sixtieth days of storage. The evaluators were 50 people who were selected from the experts working in Pegah Kerman factory and students familiar with the characteristics of cheese. Samples (100 g packages) were removed from the refrigerator before the test and after reaching the ambient temperature in 30 g pieces were given to the evaluators.
Samples were assessed for their characteristics including flavor, odor, color, texture and overall acceptance. Mean data of the first and sixtieth days were reported (Beigomi *et al*., 2013).

Texture analysis test

A texture analyzer equipment (model QTS25, FARNEL CNS, UK) and a cylindrical probe with a diameter of 36 mm were utilized for the texture profile analysis (TPA) test. The cheese samples were removed from the refrigerator before the test and after slicing (20 × 20 ×20 mm) up to 50% of the initial height (10 mm depth) was compressed by the machine. Each test was performed in at least three replications. The measured traits were: hardness, cohesiveness, adhesiveness, chewiness, springiness, and gumminess. It should be noted that the TPA test is a two-step test and these traits were defined according to the standard TPA curve (Hosseini *et al*., 2013).

Microbial tests

1- Total microbial count

The total microbial count was performed using a PCA (Plate Count Agar) at 37°C for 48 h. The number of bacteria in cheese samples was calculated as follows (Rezaei *et al*., 2010).

Microbial content /g of cheese = number of colonies × inverse dilution coefficient × 10

Mold and yeast count

YGC (Yeast Extract Glucose Chloramphenicol) medium was used for mold and yeast (fungi) count at 25°C for 48-72 h. After incubation, the obtained colonies were counted using the equation of the previous section (Rezaei *et al*., 2010).

Statistical analysis

The experiments were conducted in a factorial experiment based on completely randomized design and the experimental data were analyzed with SPSS: 21 software. Factors included treatments (4 levels) and storage time (5 levels).The means were compared using the Duncan's multiple range test with a 5% confidence level. All experiments were carried out in triplicate.

Results and Discussion

The effect of treatments on the pH

The findings in Table 1 demonstrate that the pH of cheese samples significantly reduced as storage time was increased. The lowest pH reduction was observed for cheese samples coated with AVG and 150 ppm of lemon peel EO. The pH of control treatment was found to be the lowest at the end of the maintenance time, whereas the other treatments were not significantly different (p> 0.05).

Table 1. The effect of treatments on the pH of samples.

Treatments	Day 1	Day 15	Day 30	Day 45	Day 60
Control	$5.50±0.1^{Ab}$	$5.43±0.05^{ABb}$	$5.28±0.12^{Cb}$	$5.09±0.1^{CDb}$	$4.86±0.14^{Ec}$
AVG	$5.86±0.09^{Aa}$	$579±0.1^{Aba}$	$5.57±0.05^{Ca}$	$5.36±0.1^{Da}$	$5.10±0.06^{Eab}$
AVG + 100 ppm EO	$5.85±0.11^{Aa}$	$5.75±0.15^{Aba}$	$5.58±0.2^{Ca}$	$5.35±0.08^{Da}$	$5.16±0.1^{Eab}$
AVG + 150 ppm EO	$5.83±0.1^{Aa}$	$5.75±0.08^{Aba}$	$5.57±0.05^{Ca}$	$5.57±0.05^{CDa}$	$5.25±0.12^{Da}$
P value	0.013	0.004	0.003	0.004	0.049

* Mean values in each column that have different lower-case letters have a significant difference (p < 0.05).
* Numbers in each row that have different capital letters have a significant difference (p < 0.05).

The effect of the treatments on the acidity

Table 2 shows that the acidity of the cheese samples was significantly influenced by the type of coating used as well as the storage time. The treatment coated with AVG and 150 ppm EO and control had the greatest and lowest acidity, respectively, on the sixtieth day. The acidity of the treatments increased as storage duration increased, and this increase was significant in all investigated treatments on all storage days. In cheese samples coated with AVG and 150 ppm of lemon peel EO, minimal acidity changes were seen at the end of storage period.

Table 2. The effect of treatments on the acidity of samples.

Treatments	Day 1	Day 15	Day 30	Day 45	Day 60
Control	1.46 ± 0.05^{Ea}	1.77 ± 0.09^{Da}	2.11 ± 0.2^{Ca}	2.66 ± 0.09^{Ba}	3.26 ± 0.1^{Aa}
AVG	$1.26\pm0.\ 1^{Eb}$	1.56 ± 0.1^{Db}	1.80 ± 0.18^{Cb}	2.16 ± 0.1^{Bb}	2.70 ± 0.05^{Ab}
AVG + 100 ppm EO	1.23 ± 0.08^{Eb}	1.55 ± 0.1^{Db}	1.81 ± 0.1^{Cb}	2.05 ± 0.06^{Bbc}	2.66 ± 0.11^{Abc}
AVG + 150 ppm EO	1.26 ± 0.08^{Eb}	1.50 ± 0.1^{CDb}	1.67 ± 0.15^{Cb}	1.93 ± 0.1^{Bc}	2.52 ± 0.15^{Ac}
P value	0.004	0.004	0.033	0.044	0.004

* Mean values in each column that have different lower-case letters have a significant difference ($p < 0.05$).
* Numbers in each row that have different capital letters have a significant difference ($p < 0.05$).

By increasing the storage time, a reduction in pH values of all samples were observed which may be related to the activity of lactic acid bacteria species owing to the metabolization of lactose to lactate and produce acid (Dermiki *et al*., 2008). Ramos *et al*. (2012) found that the pH of cheeses coated with whey protein isolate, guar gum and antimicrobial substances decreased with increasing storage time, and the coated cheeses had a higher pH than the control. Jamshidi *et al*. (2018), used a coating of AVG and Persian gum in Iranian white cheese, and reported that during storage, the pH decreased significantly while the acidity increased. Over time, the acidity of the various treatments increased, indicating that an increase in lactic acid production by the bacteria may be the main reason for this trend, which is definitely consistent with the decreasing trend observed in pH during storage.

El-Sisi *et al*. (2015) showed that the acidity of chitosan-coated cheeses increased during storage. A study also revealed that the acidity of cheddar cheese samples coated with whey protein increased during ripening (Wagh *et al*., 2013).

On the sixtieth day, the lowest amount of acidity was observed in cheese samples coated with AVG and lemon peel EO, which could indicate the lowest bioavailability of lactic acid bacteria (starter and non-starter) in these samples; Because more activity of lactic acid bacteria leads to more decomposition of lactate and production of organic acids such as lactic acid and acetic acid, and AVG and lemon peel EO probably due to antimicrobial activity decreased growth of these bacteria in cheese samples (Wagh *et al*., 2013).

The effect of treatments on the salt content

According to results of Table 3, the control had the most salt content at all storage times, while the other treatments were not significantly different ($p > 0.05$). The salt content of the treatments enhanced with increasing storage period, although this rise was not significant in samples coated with AVG and 150 ppm lemon peel EO ($p > 0.05$).

Table 3. The effect of treatments on the salt content (%) of cheese samples.

Treatments	Day 1	Day 15	Day 30	Day 45	Day 60
Control	3.26 ± 0.25^{Ba}	3.30 ± 0.2^{ABa}	3.41 ± 0.1^{ABa}	3.50 ± 0.2^{Aa}	3.57 ± 0.1^{Aa}
AVG	2.76 ± 0.1^{Bb}	2.81 ± 0.5^{ABb}	2.86 ± 0.25^{Ab}	2.96 ± 0.1^{Ab}	3.06 ± 0.15^{Ab}
AVG + 100 ppm EO	2.73 ± 0.3^{Bb}	2.80 ± 0.5^{ABb}	2.86 ± 0.21^{Ab}	2.93 ± 0.09^{Ab}	3.07 ± 0.15^{Abc}
AVG + 150 ppm EO	2.73 ± 0.17^{ABb}	2.80 ± 0.44^{ABb}	2.87 ± 0.23^{Ab}	2.94 ± 0.15^{Ab}	2.98 ± 0.17^{Ac}
P value	0.007	0.002	0.001	0.001	0.001

* Mean values in each column that have different lower-case letters have a significant difference ($p < 0.05$).
* Numbers in each row that have different capital letters have a significant difference ($p < 0.05$).

It can be seen that all the coated samples have less salt than control, which is consistent with the results of other researchers who have studied the effect of coating on the properties of cheese (Ramos *et al*., 2012; Yilmaz and Dagdemir, 2012). On the other hand, during the 60 days of storage, the salt content of samples increased slightly as a result of weight loss due to the removal of moisture from the cheese texture.

The effect of treatments on the moisture content

The effect of the treatments on the moisture content of cheese samples is shown in Table 4. The results reveal that the coating treatments and storage period had a significant effect on the moisture content. As storage time increased, the moisture content of samples decreased. Cheese samples with coatings retained moisture significantly more than the control. There was no significant difference in the moisture content of all treatments on the first day of storage ($p > 0.05$).

Table 4. The effect of treatments on the moisture content (%) of samples.

Treatments	Day 1	Day 15	Day 30	Day 45	Day 60

Control	63.30±4.2^{Aa}	61.73±2.9^{Ab}	60.76±2.1^{ABb}	58.66±3.3^{Bb}	58.73±4.1^{Bb}
AVG	64.15±3.1^{Aa}	64.66±4.3^{Aa}	62.70±2.5^{ABab}	61.67±3.1^{Ba}	61.33±4.2^{Ba}
AVG + 100 ppm EO	64.60±4.0^{Aa}	64.73±4.2^{Aa}	63.00±2.1^{Aa}	62.08±3.5^{ABa}	61.40±3.8^{Ba}
AVG + 150 ppm EO	64.20±4.1^{Aa}	64.84±3.9^{Aa}	63.43±2.4^{ABa}	62.64±3.4^{Ba}	61.44±4.3^{Ba}
P value	0.006	0.032	0.007	0.000	0.033

* Mean values in each column that have different lower-case letters have a significant difference ($p < 0.05$).
* Numbers in each row that have different capital letters have a significant difference ($p < 0.05$).

The cheese samples' moisture gradually decreased during the storage period as a result of some moisture being released from the texture of the cheese and the packaging to the outside. The difference between the coated samples is probably due to the composition of the coating as well as the kinetics of water influence and outflow into the various coatings (Pantaleão *et al*., 2007). Jamshidi *et al*. (2018) reported that almost all cheeses coated with AVG and Persian gum showed higher moisture content than the control, which indicates the positive effect of coating on moisture retention in cheese during storage. Coating with aloe vera gel had a barrier property for moisture loss in several fruits such as peach (Mohammadi et al., 2020), plum (Martinez-Romero et al., 2018), grapes, fresh cut papaya (Farina et al., 2020), and tomato fruit (Tzortzakis et al., 2019).

The effect of treatments on the sensory properties

Table 5 shows that with the exception of the color index, the effects of the tested treatments on the sensory characteristics of samples are significant. The highest taste score was related to the treatment coated with AVG and 100 ppm of lemon peel EO + the lowest taste score was related to the control and the AVG and 150 ppm of lemon peel EO treatments. The highest and lowest odor scores were observed in AVG with 100 ppm of lemon peel EO treatment and control, respectively. Samples coated with AVG and different concentrations of EO did not show significant differences in terms of texture ($p > 0.05$) and the lowest texture score was assigned to the control. In terms of general acceptance, AVG with 100 ppm of lemon peel EO treatment received the highest score.

Table 5. The effect of treatments on the sensory properties of samples.

Treatments	Taste	Odor	Color	Texture	General acceptance
Control	4.36±0.1^{c}	4.45±0.05^{c}	4.92±0.1	4.53±0.15^{c}	4.42±0.08^{cd}
AVG	4.59±0.05^{b}	4.63±0.1^{b}	4.96±0.1	4.67±0.1^{b}	4.78±0.12^{b}
AVG + 100 ppm EO	4.97±0.06^{a}	4.89±0.12^{a}	4.96±0.15	4.91±0.05^{Aa}	4.95±0.06^{a}
AVG + 150 ppm EO	4.36±0.05^{c}	4.75±0.16^{b}	4.97±0.09	4.89±0.12^{a}	4.54±0.1^{c}
P value	0.001	0.001	0.56	0.000	0.003

* Mean values in each column that have different lower-case letters have a significant difference ($p < 0.05$).

Most sensory panelists reported a bitter taste for cheeses containing 150 ppm of lemon peel essential oil. According to research of Yilmaz and Dagdemir (2012), there were no significant differences in the color of cheese samples coated in beeswax compared to the control, which is consistent with the findings of this investigation.

Abbas *et al*. (2017) reported that adding 0.005 and 0.010 µl of basil essential oil to UF soft cheese significantly improved the taste throughout the freshness of cheese and during the 60 days of storage time. According to this report, the desirability of samples containing low concentration (0.005 µl per 100 ml) was higher than the samples containing high concentration (0.010 µl / 100 ml). Mohammadi *et al*. (2011) reported that 100 mg/kg of basil essential oil improved the odor, taste and acceptability of white cheese during the production and storage, however, the taste and acceptability of the cheese samples were adversely affected by the essential oil concentrations of 150 and 200 mg/Kg.

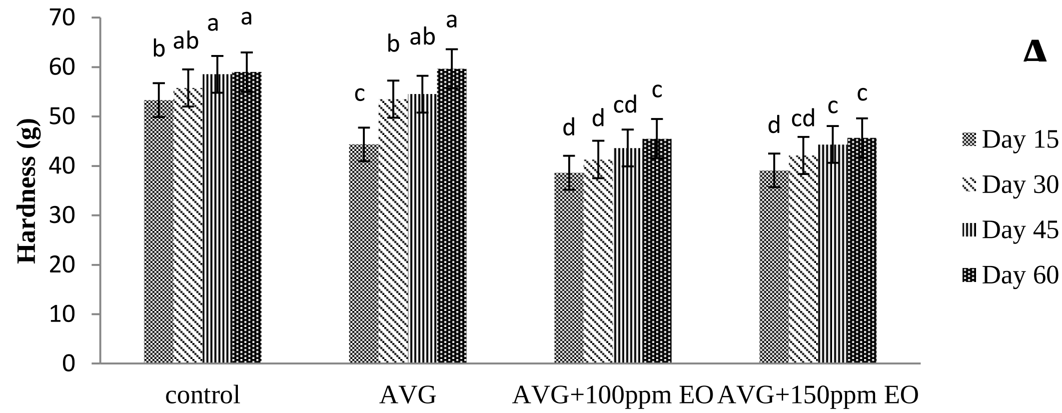
According to Otero *et al*. (2014), sheep cheese samples covered with edible films containing antimicrobial agents had improved sensory properties. The results of Pieretti *et al*. (2019) showed that cheese samples coated with alginate and low concentrations of oregano essential oil had better sensory acceptance than the control and higher concentrations of essential oil.

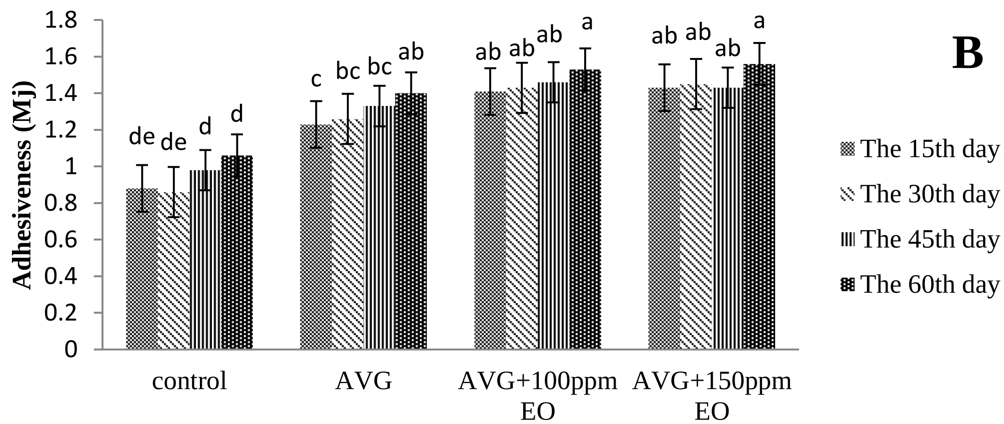
The effect of the treatments on the textural characteristics

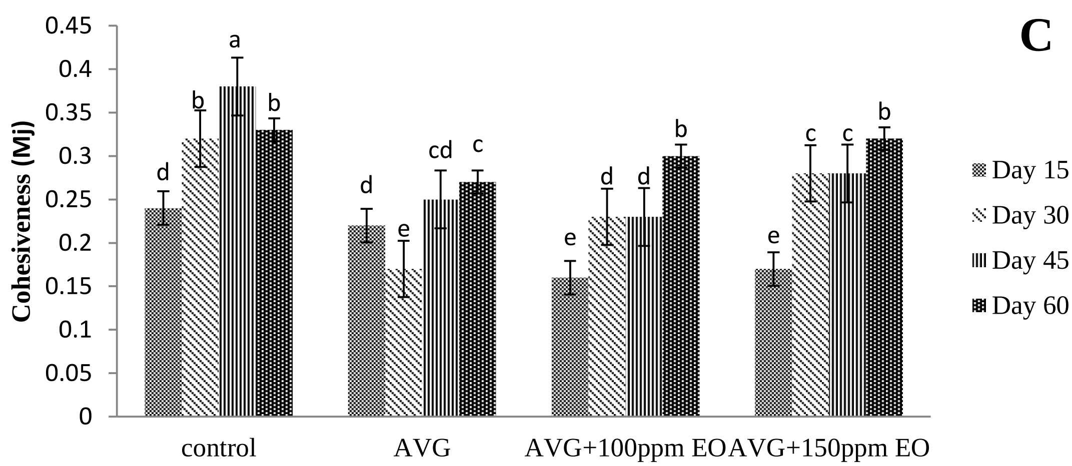
The effect of the studied treatments on the textural characteristics of cheese samples is shown in Figure 1 (A-F).

1- Hardness

According to Fig. 1(A), the coating and storage duration both significantly affected hardness. The hardness of the samples increased with storage time. On 60^{th} day, the AVG with 100 and 150 ppm of lemon peel EO had the lowest hardness while the control and AVG treatments had the highest hardness.


A
Hardness (g)
control
AVG
AVG+100ppm EO
AVG+150ppm EO
Day 15
Day 30
Day 45
Day 60


B
Adhesiveness (Mj)
control
AVG
AVG+100ppm EO
AVG+150ppm EO
The 15th day
The 30th day
The 45th day
The 60th day


C
Cohesiveness (Mj)
control
AVG
AVG+100ppm EO
AVG+150ppm EO
Day 15
Day 30
Day 45
Day 60

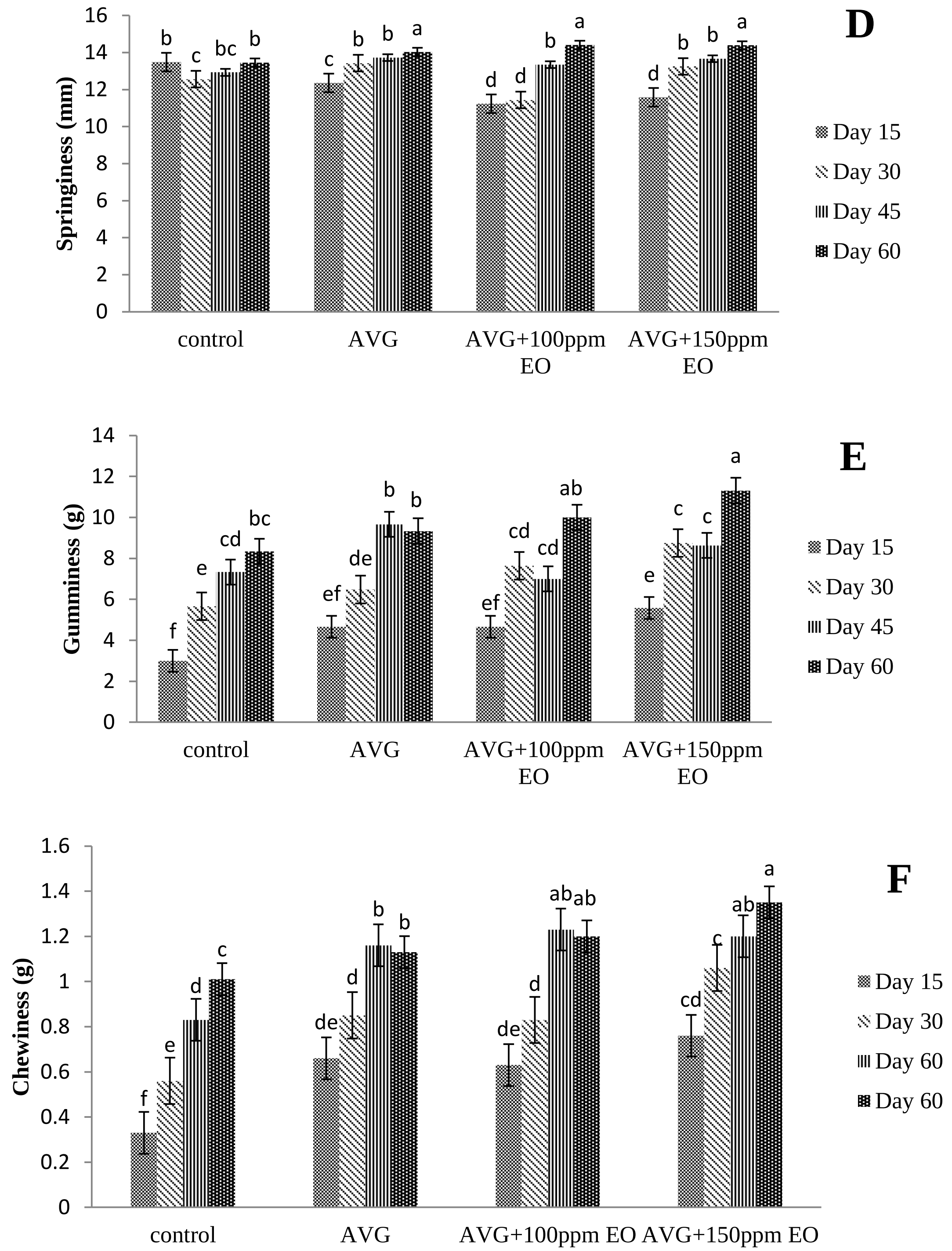


Figure 1. The effect of treatments on the hardness (A), Adhesiveness (B), cohesiveness (C), springiness (D), gumminess (E), and chewiness (F) of samples.

2- Adhesiveness

Fig. 1(B), shows that although numerically the adhesiveness of the samples increased during storage, the storage time had no significant effect on the adhesiveness of samples. At the end of storage, samples coated with AVG and 150 ppm of lemon peel EO showed the highest adhesiveness, which did not show a significant difference with the AVG and 100 ppm of lemon peel EO treatment ($p > 0.05$). The lowest adhesiveness was related to the control.

3- Cohesiveness

Fig. 1 (C), shows that the AVG treatment had the lowest cohesiveness at the end of the storage period, with no other treatments significantly different ($p > 0.05$).

4- Springiness

According to Fig. 1(D), No particular trend in the springiness of samples during storage time was seen in the control. In other treatments, springiness of samples increased with increasing storage time. On the sixtieth day, the highest springiness was related to AVG treatments with 100 and 150 ppm of lemon peel EO and the lowest amount of springiness was related to control.

5-Gumminess

According to Fig. 1 (E), it can be seen that at the end of the storage, the highest and lowest gumminess were observed in the treatment coated with AVG+150 ppm lemon peel EO and the control, respectively. The gumminess of samples significantly increased as the storage time rose.

6- Chewiness

Fig. 1(E) shows that the chewiness of samples increased as storage time increased. In the samples coated with AVG and AVG containing 100 and 150 ppm of lemon peel EO on the forty-fifth and sixtieth days, this enhancement was not significant ($p > 0.05$). On the sixtieth day, the lowest amount of chewiness was observed in the control and samples coated with AVG and the highest amount of chewiness was observed in the samples coated with AVG and 150 ppm of lemon peel EO.

According to the findings of the textural characteristics, the hardness of the samples increased with increasing storage time, which may be related to moisture loss during storage. Another factor contributing to the samples' increased hardness during storage is likely an increase in protein-protein interactions (Bianchi *et al*., 2021). It was also observed that the coated samples had less hardness than the control. It seems that more moisture in the coatings and more hydration may reduce the hardness of the samples (Zhong *et al*., 2014).

Pieretti *et al*. (2019) examined how rosemary and oregano EOs and alginate-based edible coatings affected the textural characteristics of fresh cheese, and they found that at the end of the storage period, the coated samples had less hardness than the control.

At the end of the storage time, the highest amount of adhesiveness was observed in the samples coated with AVG and 150 ppm lemon peel EO and the lowest amount of adhesiveness was related to the control. In the research of Wang *et al*. (2019), cheddar cheese samples coated with isolated whey protein nanofibrils and carvacrol showed more adhesiveness than uncoated samples.

The cohesiveness of the samples increased with increasing the storage time, and at the end of the storage, the treatment with the lowest cohesiveness was in the presence of AVG; the other treatments did not significantly differ from each other. In the study reported by Wang *et al*. (2019), the cohesiveness of coated cheese samples increased with increasing storage time, while no significant difference was observed in the other samples.

With increasing storage period, the chewiness of samples increased. This is in line with the hardness and gumminess properties. On the sixtieth day, the highest amount of chewiness was related to the treatment coated with AVG and 150 ppm of lemon peel EO. From a sensory point of view, it is perceived that more energy is needed to chew the coated samples. It was found that the chewiness of cheese samples coated with starch and carvacrol increased with increasing storage, and the coated samples had more chewiness than the control (López-Córdoba, 2021).

The effect of treatments on microbial count of samples during storage

1- The total microbial count

Table 6 shows the effect of the treatments on the total microbial count of the samples. This table shows that the total microbial count was significantly affected by both storage times and coatings. The total microbial count increased with increasing storage time. The sample coated with AVG and 150 ppm of lemon peel EO had the lowest microbial count. In general, the coated treatments showed less microbial count than the control.

Table 6. The effect of treatments on the total microbial count (log cfu/g) of samples.

Treatments	Day 1	Day 15	Day 30	Day 45	Day 60
Control	4.87±0.15^{Ca}	4.88±0.1^{Ca}	4.94±0.21^{Ba}	4.98±0.15^{Ba}	5.37±0.2^{Aa}
AVG	3.64±0.1^{Db}	3.73±0.14^{Cb}	4.60±0.15^{Bb}	4.64±0.11^{Bb}	4.82±0.1^{Ab}

AVG + 100 ppm EO	3.38±0.22^{Dc}	3.55±0.21^{Cc}	3.96±0.25^{Bc}	4.30±0.1^{Ac}	4.31±0.14^{Ac}
AVG + 150 ppm EO	2.71±0.12^{Ed}	2.92±0.2^{Dd}	3.73±0.1^{Cd}	3.81±0.25^{Bd}	3.92±0.21^{Ac}
P value	0.001	0.002	0.001	0.000	0.003

* Mean values in each column that have different lower-case letters have a significant difference ($p < 0.05$).
* Numbers in each row that have different capital letters have a significant difference ($p < 0.05$).

2- The total mold and yeast count

Table 7 shows that there is significant variation in the total number of mold and yeast in cheese samples depending on the various treatments and storage time. The total amount of mold and yeast increased with more storage time across all treatments, with the control having the highest levels. The lowest amounts of mold and yeast were found in samples that had been coated with AVG and EO.

Table 7. The effect of treatments on total mold and yeast count (log cfu/g) of cheese samples.

Treatments	Day 1	Day 15	Day 30	Day 45	Day 60
Control	3.34±0.2^{Ea}	3.82±0.13^{Da}	3.96±0.15^{Ca}	4.13±0.14^{Ba}	4.62±0.1^{Aa}
AVG	3.17±0.15^{Eb}	3.45±0.21^{Db}	3.81±0.11^{Cb}	4.01±0.1^{Bb}	4.15±0.2^{Ab}
AVG + 100 ppm EO	0.00^{Dc}	3.11±0.1^{Cc}	3.47±0.22^{Bc}	3.76±0.1^{Ac}	3.92±0.21^{Ac}
AVG + 150 ppm EO	0.00^{Ec}	0.00^{Dd}	3.06±0.1^{Cd}	3.47±0.12^{Bd}	3.76±0.15^{Ad}
P value	0.001	0.002	0.003	0.001	0.002

* Mean values in each column that have different lower-case letters have a significant difference ($p < 0.05$).
* Numbers in each row that have different capital letters have a significant difference ($p < 0.05$).

In general, the coated treatments showed less microbial, mold and yeast counts than the control. Numerous studies have focused on the antibacterial effects of AVG and lemon peel EO (Nielsen and Rios, 2000; Irshad *et al*., 2011; Roy *et al*., 2007).

Aloin and aloe-emodin are the two main components of aloe vera gel. Several researchers have confirmed the antifungal and anti-bacterial properties with improved moisture and gas barrier properties of aloe vera gel based edible coating (Ortega-Toro *et al*., 2017)

AVG as a coating can create a physical barrier against microorganisms and reduce the occurrence of microbial spoilage (Asghari and Khalili, 2014). AVG inhibits the germination and growth of fungal mycelium and the inhibitory effect of its compounds on the activity of enzymes of pathogenic fungi has been proven (Reynolds and Dweck, 1999). Saritha *et al*. (2010) reported that the antimicrobial activity of AVG against gram-positive bacteria was higher than gram-negative bacteria. Navarro *et al*. (2011) also reported that AVG controls the *Rhizopu stolonifer*, *Botrytis cinerea* and *Penicillium digitatum*. Leitgeb *et al*. (2021) investigated the effect of two aloe vera cultivars gel on different bacteria and fungi and reported that both aloe vera cultivars gel inhibited the growth of *Bacillus cereus*, *Staphylococcus aureus*, *E. coli*, *Pseudomonas aeruginosa*, *P. fluorescens* and *Candida albicans*, representatives of Gram-positive bacteria, Gram-negative bacteria, and fungi. The antibacterial properties of aloe vera are due to its constituents, which include saponins, acemannan, and anthraquinone derivatives. Therefore, the presence of these substances and antibacterial compounds in the AVG can reduce spread of germs in the treated samples (Ramasubramanian *et al.*, 2010).

Essential oils have different mechanisms in destroying microorganisms. These compounds enter the lipids of cell membranes and mitochondria, and this causes a difference in the structure of cells and their greater permeability, resulting in the release of ions and other cell contents. The release of large amounts of cellular contents or the release of vital molecules and ions causes cell death (Pauli, 2006). There are several reports about the antimicrobial effect of citrus EOs and extracts (Chanthaphon *et al*., 2018; Tan *et al*., 2011). Antimicrobial properties of lemon peel EO are related to its active ingredients. Limonene is the main monoterpene compound of lemon peel and other citrus EOs, which has antibacterial and antiviral properties (Espina *et al*., 2011; Roy *et al*., 2007). Artiga-Artigas *et al*. (2017) studied the antimicrobial effect of edible coating containing different concentrations of oregano EO on low-fat cheese. Their results showed that coatings containing oregano EO significantly reduced the microbial population during storage.

Conclusion

The use of edible coating of AVG and lemon peel EO on cheese improved the appearance and prevented textural changes during storage. Lower concentrations (50 and 100 ppm) of lemon peel EO were suitable for obtaining cheeses with better sensory properties. The coatings maintained properties such as moisture, pH, hardness, etc. The lowest microbial, mold and yeast counts were observed in the treatments coated with AVG and 150 ppm of lemon peel EO. In general, the coated treatments showed less microbial, mold and yeast counts than the control.

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تاثیر پوشش فعال مبتنی بر ژل آلوئه ورا با اسانس پوست لیمو بر ماندگاری و ویژگی های کیفی پنیر

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چکیده

در این مطالعه تأثیر پوشش خوراکی ژل آلوئه ورا حاوی اسانس پوست لیمو (0، 100 و 150 پی پی ام) بر ویژگی های کیفی نمونه های پنیر مورد بررسی قرار گرفت. تیمارها شامل 4 گروه کنترل (بدون پوشش)، ژل آلوئه ورا، ژل آلوئه ورا و 100 پی پی ام اسانس پوست لیمو و ژل آلوئه ورا و 150 پی پی ام اسانس پوست لیمو بود. این تیمارها به مدت 60 روز از نظر خواص فیزیکوشیمیایی، بافتی، حسی و شمارش میکروبی مورد ارزیابی قرار گرفتند. یافته‌ها نشان داد که با افزایش مدت نگهداری، اسیدیته و نمک افزایش و pH و رطوبت کاهش یافت. در ارزیابی ویژگی‌های حسی، تأثیر تیمارها بر تمامی ویژگی‌های حسی به جز امتیاز رنگ معنی‌دار بود. نمونه های پوشش داده شده با ژل آلوئه ورا و 100 پی پی ام پوست لیمو بالاترین امتیاز طعم (4/97) را دریافت کردند. با افزایش زمان نگهداری، سختی، قابلیت جویدن و فنری بودن نمونه های پنیر افزایش یافت. چسبندگی نمونه ها تحت تاثیر مدت زمان نگهداری قرار نگرفت. در پایان زمان نگهداری، بیشترین شمارش کل میکروبی، کپک و مخمر مربوط به نمونه های پنیر شاهد (به ترتیب 5/37 و 4/62 log cfu/g) و کمترین مقدار مربوط به نمونه های پوشش داده شده با ژل آلوئه ورا و 100 پی پی ام پوست لیمو (به ترتیب 3/92 و 3/76 log cfu/g). به طور کلی استفاده از پوشش خوراکی تهیه شده با یل آلوئه ورا و غلظت های کمتر اسانس پوست لیمو (100 پی پی ام و کمتر) باعث بهبود ظاهر و طعم نمونه های پنیر طی 60 روز نگهداری گردید.

واژگان کلیدی: آلوئه ورا، پوشش خوراکی، اسانس پوست لیمو، پنیر، خواص بافتی، ارزیابی حسی.