Research Article

Study of Effect of Using a Bio-Alginate Coating Enhanced With Lemongrass Oil Cymbopogon Citratus to Reduce Microbial Spoilage in Edam Cheese

Al-Badri Hamed Wafeeq[1] Azhar J. S. Al-Moussawi[2] and Sahar G. Imran[3]

[1]Department of Food Sciences, College of Agriculture, University of Wasit, Iraq; [2]Department of Food Sciences, College of Agricultural Engineering Sciences, University of Baghdad, Iraq; [3]Scientific Research Commission, Environment Water and Renewable Energy Technology Research Center.

Abstract | The study was applied to evaluate the effectiveness of an edible coating composed of sodium alginate enriched with lemongrass oil in inhibiting fungal growth and protecting Edam cheese during refrigerated storage. The experiment involved laboratory-produced Edam cheese and encasing it in two alginate coatings. Three treatments were prepared: Treatment A, in which the cheese was encased in paraffin wax, served as a control. The outer surface of the coating was then examined using a scanning electron microscope (SEM). Treatment B, in which the cheese was encased in a 0.2% sodium alginate coating; Treatment C, in which the cheese was encased in a 0.2% sodium alginate coating enriched with 0.5% lemongrass oil. After preparing the cheese treatments, they were evaluated during a 60-day storage period using microbiological tests, including total counts, mold, proteolytic, and lipolytic bacteria. Sensory evaluation was also performed. The results showed that Treatment C was superior in reducing mold growth compared to the other treatments. This treatment also received the best sensory evaluation throughout the storage period, with no fungal growth observed. The results of this study indicate the effectiveness of bio-coatings enriched with lemongrass oil as a natural means of preserving cheese and preventing fungal spoilage during storage.

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***Correspondence** | Al-Badri Hamed Wafeeq, Department of Food Sciences, College of Agriculture, University of Wasit, Iraq. **Email:** hamidwafeeq@uowasit.edu.iq
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Introduction

Cheese is a sensitive, perishable food product due to its high moisture, protein, and fat content, which promotes the growth of microorganisms such as yeasts and fungi. Edam cheese is a popular variety worldwide, but it is susceptible to microbial spoilage, which reduces its quality and acceptability (Kure and Skaar, 2019). Several recent studies indicate that essential oils are highly effective in inhibiting the growth of microorganisms, as they contain numerous phenolic and terpene compounds (Motelica *et*

al., 2021). Coliforms over 21 days at 1 ± 5 °C, and preserved sensory attributes like flavor, texture, color, and bitterness (Ismael and Hadi, 2024). Moreover, locally produced lemongrass oil from Abu Ghraib demonstrated total absence of *S. aureus* and coliforms in Iraqi soft cheese after 21 days, with superior sensory quality compared to thyme or rosemary oils (Kamona and Alzobaay, 2021; Ismael and Hadi, 2024). Lemongrass oil (*Cymbopogon citratus*) is important oil in this field.

Its anti-yeast and anti-fungal efficacy was observed when incorporated into sodium alginate coatings at concentrations ranging from 0.25–1%, demonstrating significant inhibition of *Penicillium*, *Rhizopus*, and *Aspergillus* species (Cofelice *et al*., 2021). At higher concentrations around 5% lemongrass oil has been shown to reduce bacterial growth when applied in alginate coatings (Irianto *et al*., 2021). Its packaging was found to be Edible coatings using natural polymers enhance the shelf life of food products by reducing external contamination and chemical degradation, without impairing the product's sensory qualities (Azeredo *et al*., 2022). This concept is further supported by the findings of (Shahdadi *et al*., 2023), who reported that adding *Mentha longifolia* essential oil to alginate chitosan-based edible films led to a noticeable reduction in the growth of harmful bacteria in lactic cheese. Their results highlight the promising role of natural essential oils as active antimicrobial components in coating systems aimed at extending the safety and shelf life of dairy products.

Sodium alginate is one of the most prominent materials used in this field, due to its ability to form non-toxic, biodegradable coatings and its easy application to food surfaces (Irianto *et al*., 2021). Furthermore, incorporating essential oils into biocoatings enhances antifungal stability, helping to inhibit the growth of spoilage pathogens (Motelica *et al*., 2021; Mahcene *et al*., 2021). Spectroscopic analyses such as FTIR have also revealed that the oil's active compounds interact chemically within the polymer network, improving water resistance and reducing moisture loss and seepage (Alarcon-Moyano *et al*., 2017; Guo *et al*., 2021). Therefore, this study used a biocoating composed of sodium alginate enriched with 5% lemongrass oil. As an edible coating for Edam cheese packaging. Thus, the aim of study was to evaluate effect on inhibiting fungal and microbial growth, improving sensory qualities and extending product shelf life during refrigerated storage.

Materials and Methods

Preparation of the coatings used in cheese packaging

The coatings used to package cheese samples were prepared based on the approved coating manufacturing methods described by Falguera *et al*. (2021), as follows: Sodium alginate coating: 2% (w/v) sodium alginate powder was dissolved in sterile distilled water, with continuous stirring using a heating device equipped with a magnetic stirrer until completely dissolved. To ensure homogeneity of the solution, the temperature was gradually raised to 50°C during preparation.

Sodium alginate coating enriched with essential oil: The coating enriched with essential oil was prepared after preparing the basic alginate solution (see above). A 5% v/v concentration of essential oil was added to the coating (this concentration was selected according to the previous section), with continuous stirring to ensure homogeneous distribution of the active ingredients within the coating solution. Food grade paraffin wax supplied to the General Company for Dairy Products - Abu Ghraib - Baghdad was used in the packaging process for the control sample. After preparing the solutions, they were used directly in the cheese packaging process by immersing the cheese pieces in the various solutions.

Identification of the outer surface of the coating using a scanning electron microscope (SEM)

Examinations were conducted on the prepared packaging under study consisting of sodium alginate and essential oil, to determine the outer surface of the packaging using a scanning electron microscope at the Chemical and Petrochemical Research Center of the Industrial Research and Development Authority.

Manufacturing of edam cheese

Edam cheese was manufactured in the dairy laboratory of the College of Agricultural Engineering Sciences at the University of Baghdad, located in the Abu Ghraib area, according to (Hamdy *et al*., 2022).

Cheese coating

Produced Edam cheese samples were coated using the dipping method, as described by Burt. (2004), which has proven effective in uniformly distributing the biofilm layer over the cheese surface without affecting its texture or sensory properties. To prepare three

cheese treatments (A, B, and C), the cheese slices were left to dry in a refrigerator (6 ± 1°C) for 3–5 days. For Treatment A, the cheese slices were immersed in a previously prepared paraffin wax solution for 5 seconds to coat them with a layer of paraffin wax only. For Treatment B, the cheese slices were immersed in a previously prepared 2% sodium alginate solution to coat them with a 2% sodium alginate layer only.

Treatment C was prepared by immersing cheese slices in a 2% sodium alginate solution enriched with 5% (v/v) essential oil, which had been prepared in advance. The cheese discs were immersed in the coating solutions for one minute, then removed and dried aseptically at room temperature. All treatments were then stored in a refrigerator at 6±1°C for 60 days. Microbial and sensory tests were performed every 10 days to evaluate the effectiveness of the different coatings in preserving and maintaining the cheese's safety.

Microbiological tests

Basic microbiological tests were performed to assess changes in the microbial load of the coated Edam cheese samples during refrigerated storage (every 10 days). These tests included: estimating the total bacterial count, mold and yeast counts, proteolytic bacteria counts, lipolytic bacteria counts, and total coliform counts. This was done using surface culture techniques on appropriate selective food media, as stated in (APHA, 2004).

Sensory evaluation of edam cheese

Sensory tests were done on Edam cheese samples by ten specialized judges in the Department of Food Science, College of Agricultural Engineering Sciences, University of Baghdad to evaluate the effect of edible coatings enriched with essential oils on the sensory properties of the cheese during storage. The evaluation was done using pre-prepared sensory evaluation forms derived from the proposals for edible coating applications. Abolila *et al.* (2024) compared with a standard sample coated with paraffin wax.

Statistical analysis

The statistical program SAS - Statistical Analysis System, User's Guide (2018) was used to analyze the data to study the effect of various factors (treatment and storage duration) on the studied traits, using a completely randomized design (CRD). Significant differences between means were compared using the least significant difference (LSD) test.

Results and Discussion

Identification of the external surface of the coating using a scanning electron microscopy (SEM)

A surface structure analysis of the alginate reinforced with lemongrass oil was performed using a scanning electron microscope (SEM) at the Chemical and Petrochemical Research Center of the Industrial Research and Development Authority. SEM images of the sodium alginate film reinforced with lemongrass oil showed a homogeneous surface structure, free of cracks or layer separations, indicating an even distribution of components within the polymer structure. At low magnification levels (17X to 68X) (Figure 1), subtle ripples and structural folds with diameters ranging from 1.2 to 2.8 mm were observed, reflecting structural flexibility and the ability to adapt to packaging conditions, especially for wet products.

At medium magnification (456X) to (806X)

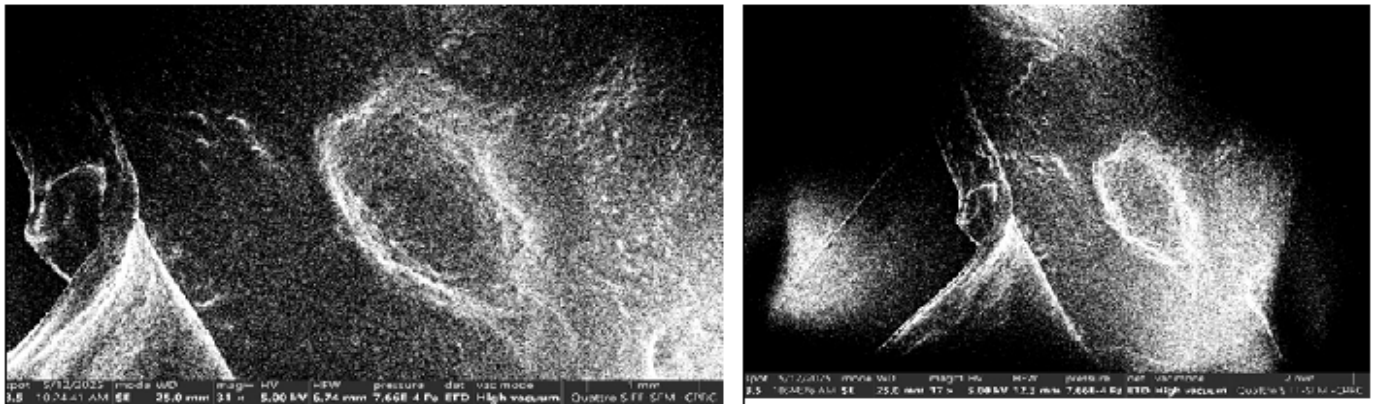

Figure 1: *The surface of the sodium alginate coating enriched with lemongrass oil using a scanning electron microscope (SEM) at magnifications of (17× - 68×)*

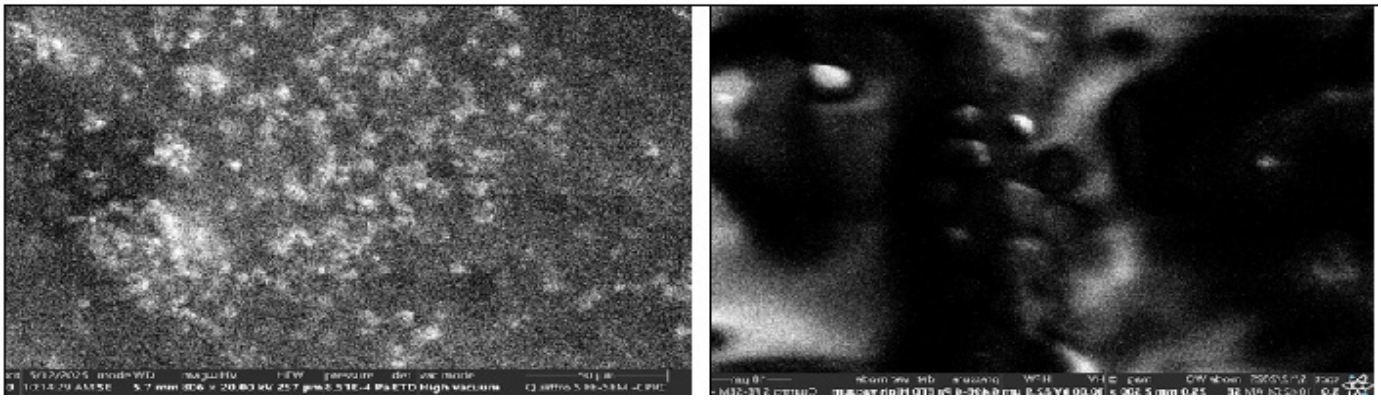

Figure 2: *the surface of the sodium alginate coating enriched with lemongrass oil using a scanning electron microscope (SEM) at magnifications of (456× to 806×)*

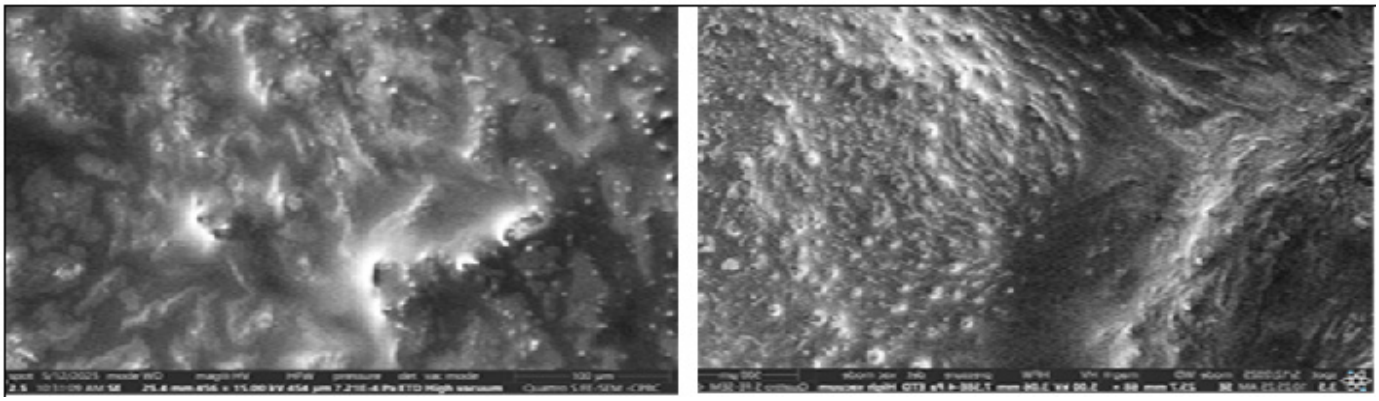

Figure 3: *the surface of the sodium alginate coating enriched with lemongrass oil using a scanning electron microscope (SEM) at a magnification of (2500×)*

(Figure 2), the patterns showed regular clusters of oil components within the polymer structure with diameters ranging from 3–7 µm indicating homogeneous incorporation of the oil within the membrane structure. The examined at magnification (2500X), small gaps (0.8–1.5) µm in size were detected, finely and regularly distributed (Figure 3), indicating the membrane's ability to contain and gradually release active compounds.

These results are agreed with Kowalonek *et al.* (2023), who observed that incorporating essential oils into alginate membranes produces a smooth, homogeneous structure that enhances mechanical and biological properties. The results are also agreed with Guzmán-Pincheira *et al.* (2025); Vargas-Ramella *et al.* (2025) that coating enhanced with essential oils such as oregano and thyme exhibit effective incorporation of components without agglomeration or separation, improving the performance of the material in food applications.

The effect of refrigerated storage on total plate count (TPC)

Monitoring the total bacterial count in foods is an important indicator of product quality and its vulnerability to microbial contamination. An increase in the total bacterial count is an indicator of product quality deterioration or inefficient preservation methods. The results showed that the total bacterial counts, when estimated at the beginning of the ripening process, were within the limits permitted by the Iraqi standard specification for microbiological tests, ranging from 2.10 to 2.36 log CFU/g in the three cheese treatments (Table 1).

A significant increase in the total bacterial count was observed as the ripening period progressed, with variations in these counts between the three treatments during the different storage periods. In treatment (A), coated with paraffin wax, the total bacterial count increased to 8 log CFU/g by day 60 of storage, highlighting the limitations of paraffin wax as a microbial barrier. This is agreed with what Sharafi *et al.* (2023) indicated in their comprehensive review, where they demonstrated that conventional coatings often fail to limit microbial growth in fresh dairy products.

In treatment (B), alginate layer was used without enhancing it with essential oil, recorded the highest increase in bacterial counts was 8.30 log CFU/g, confirming that alginate alone does not provide an environment that inhibits microbial growth (Christaki *et al.*, 2022; Sharafi *et al.*, 2023). In contrast, Treatment C, lemongrass oil was embedded in an alginate membrane, showed a significant decrease in TPC throughout the storage period, with values ranging from 2.10 log CFU/g on day 0 to 3.60 log CFU/g on day 60. This decrease is attributed to the dual effect of alginate, which forms a physical barrier against oxygen and moisture transmission, and lemongrass oil, which contains citral, a compound known for its antibacterial properties.

These results confirm the findings of several studies, including Naik *et al.* (2022) and Vargas-Ramella *et al.* (2025), who demonstrated that incorporating natural essential oils into biofilms reduces the microbial load by affecting the bacterial cell membrane. The study by Bardenshtein *et al.* (2021) was indicating that volatile oils, such as lemon oil, provide effective protection against the growth of aerobic and anaerobic bacteria when used within active packaging systems.

Effect of refrigerated storage on total coliform counts

The results indicate that coliform bacteria were not detected in all three cheese treatments A, B, and C throughout the 60-day storage period (Table 1). This absence reflects an important indicator of manufacturing safety, the quality of heat treatment, and general hygiene in the production process. It also demonstrates the effectiveness of packaging conditions in preventing secondary contamination with bacteria that indicate fecal contamination.

These results was similar with finding of Sherif *et al.* (2016) reported in their study on the microbial evaluation of local cheese products, in which they demonstrated that the absence of coliform bacteria in cheese indicates good adherence to hygienic manufacturing practices. Recent reviews have also

Table 1: *Microbial counts (log CFU) in different Edam cheese treatments during refrigerated storage at 10±2°C for 60 days*

Treatment	Storage period	Bacterial count	E. coli	Yeasts and molds	Lipolytic bacteria	Proteolytic bacteria
A	0	2.36	Nill	Nill	1.60	2.39
	10	3.95	Nill	Nill	1.77	3.50
	20	4.69	Nill	Nill	1.95	3.55
	30	6.47	Nill	5	2.17	3.61
	40	6.49	Nill	7.93	2.20	3.56
	50	7.34	Nill	8.13	2.25	3.46
	60	8	Nill	9.38	2.36	3.30
B	0	2.36	Nill	Nill	1.40	2.30
	10	4.30	Nill	Nill	2.07	2.39
	20	4.87	Nill	Nill	2.30	2.47
	30	7.96	Nill	Nill	2.54	2.53
	40	8	Nill	Nill	2.60	2.69
	50	8.17	Nill	Nill	2.66	3.47
	60	8.30	Nill	Nill	2.77	3.53
C	0	Nill	Nill	Nill	1.38	2.37
	10	Nill	Nill	Nill	1.55	2.46
	20	3.69	Nill	Nill	1.70	2.56
	30	3.60	Nill	Nill	1.84	2.69
	40	3.47	Nill	1.90	2. 0	2.51
	50	3.41	Nill	2.17	2.13	2.39
	60	3.60	Nill	2.00	2.27	2.17
LSD		2.194 *	0.00 NS	2.154 *	0.852 *	0.692 *

* **(P≤0.05)**

indicated that the application of essential oils in edible packaging contributes to reducing bacterial contamination, especially in perishable dairy products (Bukvicki *et al*., 2023). In addition, the use of lemongrass oil in C treatment may have contributed to enhancing resistance to bacterial growth, due to its content of compounds with antimicrobial activity, such as citral. Gutiérrez-Pacheco el al. (2023) demonstrated strong antibacterial and antifungal properties, and its ability to reduce the microbial load in food products and increase their shelf life.

Effect of refrigerated on the number of yeasts and molds

The results showed that the number of yeasts and molds (log CFU/g) in the three cheese treatments during the maturation period, a clear difference in the growth rates of yeasts and molds can be observed between the three cheese treatments. No yeast or mold growth was observed in Treatment A from 0 to 20 days of age. Significant growth was observed starting on day 30, reaching 5.00 log CFU/g, and continued to increase with the maturation period, reaching a maximum of 9.38 log CFU/g on day 60 (Table 1).

In Treatment B, no yeast or mold growth was observed until 10 days of age, followed by a rapid increase in their numbers starting on day 20 and continuing until the end of the maturation period, indicating a high growth density. In Treatment C, no fungal growth was observed in the cheese throughout the storage period and up to day 60, reflecting the effectiveness of the essential oil used as an antifungal.

These results indicate that the use of lemongrass oil as part of the coating formulation in Treatment C contributed to the complete inhibition of fungal growth during the storage period. This effect is due to the oil containing active compounds such as citral. The inhibitory has effect on the fungal cell wall and reducing the permeability of cell membranes, leading to the destruction of ionic balance and fungal cell death (Gutiérrez-Pacheco el al., 2023). Bukvicki *et al*. (2023) also confirmed that combining essential oils with bio-encapsulating materials such as alginate enhances the antimicrobial and antifungal effect, thus enhancing the shelf life of stored foods. On the other hand, the occurrence of fungal growth in treatments A and B is attributed to the absence of antifungal compounds, as paraffin wax does not provide microbial protection, while sodium alginate requires support with active ingredients to achieve higher efficiency. These results are agreed with Sherif *et al*. (2016) found that failure to use natural enhancers in cheese packaging leads to significant fungal growth after the third week of storage, especially under high humidity conditions.

Effect of cold storage on the number of proteolytic bacteria

The results show the number of proteolytic bacteria in the cheese treatments during the storage (ripening) periods. In Treatment A, the number of proteolytic organisms was 1.60 log CFU/g on day 0 and gradually increased with the storage period was 2.3 log CFU/g at the end of the storage period at day 60 (**1**). However, treatment B showed the highest growth rate of proteolytic bacteria compared to the other treatments, as the number increased from 1.40 log CFU/g on day 0 to 2.94 log CFU/g at the end of the ripening period. Treatment C recorded the lowest growth in the number of these bacteria, as the number increased from 1.38 log CFU/g on day 0 to 2.27 log CFU/g. These results demonstrate the effectiveness of lemongrass oil added to the coating of Treatment C in inhibiting the activity.

This activity is attributed to the oil's citral content, which affects bacterial cell metabolism and inhibits their proliferation. Furthermore, the increased number of proteolytic organisms in Treatment B demonstrates that alginate alone does not provide sufficient protection against bacterial growth unless supplemented with active compounds. These results are agreed with Fox *et al*. (2000) who reported that the activity of proteolytic bacteria is directly affected by the presence of inhibitory compounds in the culture medium, particularly in dairy products. McSweeney, (2004) has indicated that proteolysis processes are typically accelerated during storage due to the activity of bacteria capable of degrading casein. This explains the significant increase in the number of proteolytic bacteria in treatment B, which did not contain any active inhibitory agent. Therefore, it can be argued that the use of essential oil-enriched biofilms is an effective option for reducing the growth of proteolytic bacteria and slowing protein degradation during storage.

Effect of refrigerated storage on the number of lipolytic bacteria

The results of calculating the number of lipolytic bacteria showed significant increases in the number

of these bacteria during the maturation period in all treatments. In treatment A, the bacterial count increased from 1.60 on day zero to 2.36 log CFU/g at 60 days (Table 2). Treatment (B) recorded a significant increase in bacterial counts compared to treatment A, reaching 2.77 log CFU/g at the end of maturation. In contrast, treatment C was the most effective in inhibiting the growth of these bacteria, as the count began at 1.38 log CFU/g and reached only 2.27 log CFU/g at the end of the storage period.

Table 2: *Mycotoxin concentration (ppb) (ng/gm) in Edam cheese samples during a 60-day storage period at 10±2°C*

Treatment	Storage period (days)	Mycotoxin concentration (ppb) (ng/gm)	
		AflatoxinG1	Aflatoxin B1
A	0	UDL	UDL
	10	UDL	UDL
	20	UDL	UDL
	30	UDL	UDL
	40	UDL	UDL
	50	UDL	UDL
	60	UDL	UDL
B	0	UDL	UDL
	10	UDL	UDL
	20	UDL	UDL
	30	UDL	UDL
	40	UDL	UDL
	50	UDL	UDL
	60	32.9	UDL
C	0	UDL	UDL
	10	UDL	UDL
	20	UDL	UDL
	30	UDL	UDL
	40	UDL	UDL
	50	UDL	UDL
	60	UDL	UDL
LSD		4.071 *	0.00 NS
* (P≤0.05)			

This decrease in the growth of lipolytic organisms in treatment (C) indicates the effective role of the essential oil in inhibiting the enzymatic activity of lipolytic bacteria. This is agreed with Dos Santos Gouvea *et al.* (2017) reported that the use of essential oils in cheese inhibits the growth of lipolytic bacteria and preserves the sensory and physical quality of the product during storage. The results also agree with the findings of Silva *et al.* (2023), who found that natural antioxidants reduce lipolysis and reduce the growth of microorganisms responsible for cheese quality deterioration during prolonged storage.

The results of Table 1 indicate that there are clear significant differences in the numbers of microbial groups studied between the different cheese treatments during the 60-day refrigerated storage period, at a probability level of (P≤0.05). The least significant difference (L.S.D.) value (P≤0.05) was 2.194 for the total number of bacteria, 2.154 for yeasts and molds, 0.852 for lipolytic bacteria, and 0.692 for proteolytic bacteria. As for coliform bacteria, no significant differences were recorded between treatments throughout the storage period (L.S.D. = 0.00 NS). These values confirm that the differences recorded between the cheese treatments were real and not the result of random variation. It is noted that treatments A (paraffin wax) and B (alginate only) recorded gradual and significant increases in all bacterial groups throughout the storage period, reaching a peak at the end of the period, particularly in the number of yeasts and molds, which reached 9.38 Log CFU/g in treatment A and no countable limit was exceeded in treatment B. In contrast, treatment C (alginate + 0.5% lemongrass oil) showed significant positive differences, maintaining relatively low levels in microbial populations, and the numbers of bacteria and yeasts remained below critical limits. This is attributed to the inhibitory effect of the essential oil, which limits the growth of microorganisms through multiple mechanisms, including penetration of cell membranes and disruption of endogenous enzyme activity, enhancing the effectiveness of the biofilm as a microbiological protection for cheese during storage.

Estimation of mycotoxin concentrations in edam cheese samples

To confirm the absence of mycotoxins in processed Edam cheese samples, particularly aflatoxins B1 and G1, and to study the effect of lemongrass oil in reducing the presence of these toxins, The concentration of mycotoxins in cheese samples was estimated. The results showed that all cheese samples (A, B, and C) did not record detectable levels (UDL) of these toxins throughout the storage period, with the exception of treatment B (sodium alginate only), which recorded a concentration of 32.9 ng/g of aflatoxin G1 at the end of storage on day 60, while, aflatoxin B1 levels remained undetectable in all treatments (Table 2).

Statistical analysis showed that this increase in G1 toxin was statistically significant at the probability level (P≤0.05), with a L.S.D. value = 4.071, indicating a real difference between the three cheese treatments. As for B1 toxin, its levels remained undetectable (UDL) in all treatments, and no significant differences were recorded between treatments, as shown by the non-significant L.S.D. value (0.00) (NS).

These results indicate the effectiveness of lemongrass oil, which was used to reinforce the alginate coating the cheese in treatment C, in inhibiting mycotoxin production compared to the alginate coating alone used to coat the cheese in treatment B. Hassanin *et al.* (2021) found that essential oils such as clove oil and thyme oil are effective in inhibiting fungal growth in Ras cheese, reducing the risk of mycotoxin contamination. These results are agreed with Esper *et al.* (2014), who reported a significant reduction in aflatoxin B1 production when using essential oils extracted from *Ageratum conyzoides* and *Origanum vulgare*. They confirmed that some components of the oils, such as thymol, carvacrol, and citral, may inhibit the activity of enzymes responsible for mycotoxin biosynthesis. These data suggest that the use of essential oils, particularly lemongrass oil may represent an effective and safe alternative for reducing fungal contamination and the occurrence of mycotoxins in stored dairy products such as matured cheese.

Sensory evaluation of edam cheese

The sensory evaluation results are shown in the Table 3 There was a clear difference in the scores assigned to sensory attributes between the three cheese treatments during the storage period. Treatment C (coated with sodium alginate and lemongrass oil) was the best in terms of overall evaluation, with an average score of 9.52, reflecting its superiority in preserving the cheese's sensory properties throughout the storage period. This treatment received the highest scores in all sensory attributes, particularly in surface appearance, flavor, and freedom from mold growth,

Table 3: *Sensory evaluation in the three treatments of Edam cheese ripened over a period of 60 days at a temperature of 10°C*

Treatment	Storage period (days)	Appearance	Consistency and stickiness	Texture	Taste and flavor	Fat slicks	Mold growth
A	0	10	10	10	10	10	10
	10	10	10	9	9	10	10
	20	9	10	10	9	10	10
	30	10	9	9	9	10	10
	40	9	9	8	8	10	8
	50	8	8	7	8	10	7
	60	8	8	7	8	10	5
B	0	10	10	10	10	10	10
	10	10	9	9	9	9	10
	20	5	8	7	2	8	0
	30	3	7	6	2	8	0
	40	3	6	4	2	5	0
	50	2	6	2	2	5	0
	60	0	4	2	2	3	0
C	0	10	10	10	10	10	10
	10	10	10	10	9	10	10
	20	10	10	9	9	10	10
	30	9	9	9	9	10	10
	40	10	9	9	9	10	10
	50	9	9	8	9	10	10
	60	10	8	8	8	10	10
LSD		1.569*	2.083*	3.592*	3.162*	3.074*	2.822*

* (P≤0.05)

which scored 10.0. This indicates the effectiveness of lemongrass oil as an antimicrobial and sensory quality stabilizer during storage.

Sensory evaluation of Edam cheese samples was conducted over various storage periods (0, 10, 20, 30, 40, 50, and 60 days) by specialized from the Department of Food Sciences, College of Agricultural Engineering Sciences, University of Baghdad. The evaluation focused on the following characteristics: appearance, consistency and adhesion, texture, flavor, fat separation, and mold growth.

Scores ranging from 1 to 10 were used with (10) representing the highest degree of acceptability and (1) representing the lowest degree of acceptability. Descriptive comments made by the judges regarding the appearance of the coating and its changes during the storage period were recorded. The (overall rating) was used, which refers to the average overall sensory impression formed by the judge of the sample. It is derived from the sum of the scores given by the judges for the studied attributes and provides an idea of the acceptability of the product as a whole sensory experience.

These results are attributed to the inhibitory effect of microbial and enzymatic activity by the essential oils, especially lemongrass oil, and the role of alginate in providing an effective barrier against moisture and oxygen, which contributed to the preservation of flavor and texture. In contrast, Treatment A, coated with paraffin wax, scored an overall average score of 9.02 and was rated relatively well, especially in terms of its appearance. However, mold growth and flavor values gradually decreased during storage compared to Treatment C, indicating that the wax provided only mechanical insulation without any effective biological effect. Treatment B, coated with sodium alginate alone, recorded the lowest overall average score of 5.24, with a significant decrease in the scores for flavor, appearance, and mold growth.

This reflects the limited effect of alginate alone without the addition of anti-spoilage agents such as essential oils. These results are consistent with those reported by Conte *et al*. (2009), who found that the use of sodium alginate-based active coatings with antimicrobial components, such as lysozyme and Na_2-EDTA, contributed to the preservation of the sensory and microbiological properties of Fior di Latte cheese during storage, compared to the standard treatment. They attributed this effect to the ability of the active coatings to reduce moisture loss and prevent morphological changes associated with microbial growth.

Ribeiro-Santos *et al*, (2017) Found that essential oils possess antioxidant, antibacterial, and antifungal properties, enhancing their role in improving the sensory quality of preserved dairy products. These comparisons suggest that active coatings enhanced with essential oils could be an effective strategy for improving the sensory properties of cheese and extending its shelf life. LSD test results showed significant differences ($P \leq 0.05$) between treatments across all sensory attributes. Treatment C performed significantly better than treatments A and B, confirming the effectiveness of the lemongrass oil-enriched bio-coating in improving sensory attributes during storage.

Conclusions and Recommendations

The study concludes that Treatment C was higher in reducing mold growth compared to the other treatments. This treatment also received the best sensory evaluation throughout the storage period, with no fungal growth observed. The effectiveness of bio-coatings enriched with lemongrass oil as a natural means of preserving cheese and preventing fungal spoilage during storage.

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Novelty Statement

This treatment also received the best sensory evaluation throughout the storage period, with no fungal growth observed. The results of this study indicate the effectiveness of bio-coatings enriched with lemongrass oil as a natural means of preserving cheese and preventing fungal spoilage during storage.

Author's Contribution

Al-Badri Hamid Wafeeq: Conceptualization
Azher J. S. Al-Moussawi: Methodology and writing-original draft preparation,
Sahar G. Imran: Software, data curation and supervision, writing-review & editing.

Generative AI or AI assisted technology statement
The authors declare that no genrative AI was used in the creation of this manuscript.

Conflict of interest
The authors have no conflict of interest.

References

Abolila, S.H., A.I. Metwally and R.A. Awad. 2024. Evaluation of edible film based on milk protein containing different polymers and essential oils for Edam cheese coating. Egypt. J. Chem., 67(1): 34–47. https://journals.ekb.eg/article_321410.html

Alarcón-Moyano, J.K., J. Londono-Londono, C. Osorio and L.F. Gutiérrez . 2017. Alginate edible films containing microencapsulated lemongrass oil or citral: effect of encapsulating agent and storage time. J. Food Sci. Technol., 54(9): pp.2878–2889. https://doi.org/10.1007/s13197-017-2726-1

American Public Health Association (APHA) 2004. compendium of methods for the microbiological examination of foods. American Public Health Associat. Washing., DC. 4th ed. https://ajph.aphapublications.org/doi/book/10.2105/MBEF.0222?utm_source

Azeredo, H.M.C., C.G. Otoni and L.H.C. Mattoso. 2022. 'Edible films and coatings – Not just packaging materials', Curr. Res. Food Sci., 5: pp. 1590–1595

Bardenshtein, A., A. Martin, B. Marcos, E. Arranz, and F. Öz. 2021. Functional edible coatings with essential oils for antimicrobial cheese packaging. Presented at: CIRCULABILITY COST Action Conference., https://projects.au.dk/fileadmin/user_upload/CIRCULABILITY_Cost_Action/Conference_2021/Abstract/Book_of_Abstracts_complete.pdf

Bukvicki, D., M. D'Alessandro, S. Rossi, L. Siroli, D. Gottardi, G. Braschi, F. Patrignani and R. Lanciotti. 2023. Essential Oils and Their Combination with Lactic Acid Bacteria and Bacteriocins to Improve the Safety and Shelf Life of Foods: A Review. Food., 12(17): 328. https://doi.org/10.3390/foods12173288

Burt, S. 2004. Essential oils: their antibacterial properties and potential applications in foods a review. Int. J. Food Microbiol., 94(3): 223–253. DOI: https://doi.org/10.1016/j.ijfoodmicro.2004.03.022

Christaki, S., T. Moschakis, M. Hatzikamari and I. Mourtzinos. 2022. Nanoemulsions of oregano essential oil and green extracts: Characterization and application in whey cheese. Food Cont., 138: 109027. https://doi.org/10.1016/j.foodcont.2022.109027

Cofelice, M., G. Cinelli, F. Lopez, T. Di Renzo, R. Coppola and A. Reale. 2021. 'Alginate-assisted lemongrass (*Cymbopogon nardus*) essential oil dispersions for antifungal activity'. Food., 10(7): 1528. DOI: https://doi.org/10.3390/foods10071528

Conte, A., C. Scrocco, M. Sinigaglia and M.A. Del Nobile. 2009. Innovative active packaging systems to prolong the shelf life of Fior di Latte cheese. J. Dairy Sci., 92(11): 5103–5108. https://doi.org/10.3168/jds.2009-2255

Dos Santos Gouvea, F., A. Rosenthal and E.H. da Rocha Ferreira, 2017. 'Plant extract and essential oils added as antimicrobials to cheeses: a review', Ciencia Rural., 47(8). doi: https://doi.org/10.1007/s13197-020-04753-3

Esper, L.M.R., E. Gonçalez, M.O.M. Marques, J.D. Felicio and J.D. Felicio. 2014. Inhibitory effect of essential oils from Ageratum conyzoides L. and Origanum vulgare L. on the growth of Aspergillus flavus and aflatoxin B1 production. Food Sci. Technol. (Campinas)., 34(2): 329–336. https://doi.org/10.1590/fst.2014.0058

Falguera, V., J.P. Quintero, A. Jiménez, J.A. Muñoz and A. Ibarz, 2011. 'Edible films and coatings: Structures, active functions and trends in their use', Trends Food Sci. Technol., 22(6): pp. 292–303 https://doi.org/10.1016/j.tifs.2011.02.004

Fox, P.F., J.M. Wallace, S. Morgan, C.M. Lynch, E.J. Niland and J. Tobin. 2000. Cheese ripening: Biochemical and physical aspects. Int. Dairy

J., 10(7): 321–345. https://doi.org/10.1016/S0958-6946(00)00082-X

Guo, Y., R. Pizzol, S. Gabbanini, A. Baschieri, R. Amorati and L. Valgimigli. 2021. Absolute Antioxidant Activity of Five Phenol-Rich Essential Oils. Molecul., 26(17): 5237. https://doi.org/10.3390/molecules26175237

Gutiérrez-Pacheco, M.M., H. Torres-Moreno, M.L. Flores-Lopez, N. Velázquez Guadarrama, J.F. Ayala-Zavala, L.A. Ortega-Ramírez and J.C. López-Romero. 2023. Mechanisms and applications of citral's antimicrobial properties in food preservation and pharmaceuticals formulations. Antibiot., 12(11): 1608. https://doi.org/10.3390/antibiotics12111608

Guzmán-Pincheira, P., J. Romero, E. Morales, M. Rubilar and F. Acevedo. 2025. Alginate-chitosan edible films incorporating oregano and thyme essential oils: physical, barrier and antimicrobial properties. Food., 14(2): 256. https://doi.org/10.1007/s12393-010-9031-3

Hamdy, S., D. Abdelmeged and H. Abdelmontaleb. 2022. Effect of natural whey culture on the quality characteristics of Edam cheese made from pasteurized milk. J. Food Dairy Sci., 13(3): pp. 47–50. https://doi.org/10.21608/jfds.2022.125552.1040

Hassanin, F.S., H.S. El-Sayed, E.M. El-Diasty and G.M. Hassan. 2021. 'Antifungal activity of some essential oils on mycoflora and mycotoxins production in Ras cheese'. *Suez Canal Veter. Med. J.*, 26(1): pp. 1-18. https://scvmj.journals.ekb.eg/article_173989.html

Irianto, H.E., D.B.Marpaung, Giyatmi and D. Fransiska. 2021. 'Anti-bacterial activity of alginate based edible coating solution added with lemongrass essential oil against some pathogenic bacteria', IOP Conference Series: Earth Environ. Sci., 934: 012023. https://doi.org/10.1088/1755-1315/934/1/012023

Ismael, F.N. and S.T. Hadi. 2024. The Effect of thyme, rosemary, and lemongrass oils on extension of the shelf life and qualitative characteristics of Iraqi soft cheese. Func. Food. Health Dise., 14(1):1–13. DOI: https://doi.org/10.31989/ffhd.v14i1.1262

Kamona, Z.K. and AHH. Alzobaay. 2021. Effect of lemongrass essential oil on pathogenic bacteria and sensory properties of fish balls. Iraqi J. Agric. Sci., 52(2): 268–275. DOI: https://doi.org/10.36103/ijas.v52i2.1288

Kowalonek, J., J. Piątek and H. Kaczmarek. 2023. Physico-chemical properties of alginate-based films incorporated with Tanacetum vulgare essential oil. Prog. Chem. Appl. Chit. Derivat., 28(4): pp. 52–62. https://doi.org/10.3390/polym15020260

Kure, C.F. and I. Skaar. 2019. The fungal problem in cheese industry. Current Opin. Food Sci., 29: pp.14–19. https://doi.org/10.1016/j.cofs.2019.07.003

Mahcene, Z., A. Khelil, S. Hasni, F. Bozkurt, M.B. Goudjil and F. Tornuk. 2021. Home-made cheese preservation using sodium alginate based edible film incorporating essential oils. J. Food Sci. Technol., 58(6): pp.2406–2419.

McSweeney, P.L.H. 2004. Biochemistry of cheese ripening: Introduction and overview. Int. J. Dairy Technol., 57(2–3): 127–144. https://doi.org/10.1111/j.1471-0307.2004.00147.x

Motelica, L., D. Ficai, O.C. Oprea, A. Ficai, V.L. Ene, B.S. Vasile, E. Andronescu and A.-M. Holban. 2021. Antibacterial Biodegradable Films Based on Alginate with Silver Nanoparticles and Lemongrass Essential Oil Innovative Packaging for Cheese. Nanomater., 11(9): 2377. https://doi.org/10.3390/nano11092377

Naik, S.N., A. Saji, and S.B. Nagarajaiah. 2022. Antimicrobial properties of lemongrass in active coatings for food systems. World Scient. Res., https://core.ac.uk/download/pdf/524159922.pdf

Ribeiro-Santos, R., M. Andrade, N.R. de Melo and A. Sanches-Silva. 2017. Use of essential oils in active food packaging: Recent advances and future trends. Trend. Food Sci. Technol., 61: 132–140. https://doi.org/10.1016/j.tifs.2016.11.021

Shahdadi, F., M. Faryabi, H. Khan and A. Salehi Sardoei. 2023. Mentha longifolia essential oil and pulegone in edible coatings of alginate and chitosan: Effects on pathogenic bacteria in lactic cheese. *Molecul.*, 28(11): p.45 doi: 10.3390/molecules28114554

Sharafi, H., M. Moradi and K. Sharafi. 2023. A systematic review of the use of plant essential oils and extracts in antimicrobial edible films for dairy products. Veterinar. Res. Forum., 14(2): 179–188. https://pmc.ncbi.nlm.nih.gov/articles/PMC10170464

Sherif, O.S., H.A. El-Essawy and A.B. Abd El Salam. 2016. Hygienic quality and sensory evaluation of locally manufactured soft cheese. Egypt. J. Food Safet., 3(2): 1-11. DOI: https://doi.org/10.21608/ejfsj.2016.156822

Silva, N., *et al*. 2023. Natural antioxidants in cheese: impact on lipid oxidation, microbial growth, and sensory quality a review. Dairy Sci. Technol., 103(4): 555–567. https://doi.org/10.1007/s13594-023-00789-3

Vargas-Ramella, M., N. Echegaray and P.C.B. Campagnol. 2025. Natural polymer-based coatings for animal-derived products: A review of applications, functionality, characterization, and challenges. Food., 14 (13): 2255. https://www.mdpi.com/2304-8158/14/13/2255