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Harnessing the Power of Essential Oils Approach to Preserve Ras Cheese

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Abstract

This study evaluated the effectiveness of whey protein-based edible coatings enriched with essential oils—moringa, pumpkin, turmeric, and jojoba—on the quality and shelf life of Ras cheese during a 120-day ripening period. Coated cheese samples were analyzed for chemical composition, microbial counts, and sensory properties. Moringa oil-enriched coatings exhibited the highest proteolysis (SN/TN: 42.78%) and volatile fatty acid levels (TVFA: 105.81 mL NaOH/100g), enhancing flavor development. Pumpkin oil coatings scored highest in flavor and appearance, reflecting improved sensory appeal. All essential oil coatings significantly inhibited coliforms and fungal growth, improving microbiological safety. These findings demonstrate the dual role of essential oil-based coatings as protective barriers and ripening modulators, offering a natural and sustainable alternative to synthetic cheese preservatives.

Keywords: Ras cheese; Whey Protein Based Edible coating; Essential oils; Natural Food Preservation.

1. Introduction

Ras cheese is a traditional hard cheese widely consumed in Egypt and the Middle East. It has a rich history of cultural and dietary significance. It is typically produced from cow or buffalo milk through enzymatic coagulation, followed by curd processing, pressing, salting, and aging for up to six months. This cheese is known for its dense texture, nutty flavor, and extended shelf life under appropriate storage conditions [1]. Despite its popularity, Ras cheese production and storage face several challenges. Microbial contamination during ripening often compromises safety and shelf life [2]. Recent advancements have focused on utilizing whey protein-based edible coatings to address these challenges. Whey protein coatings, derived from milk processing by-products, act as semi-permeable barriers to oxygen, moisture, and lipid oxidation, reducing spoilage and extending the shelf life of cheese [3]. Incorporating bioactive compounds like essential oils into these coatings can further enhance their protective capabilities [4]. Essential oils, with their antimicrobial and antioxidant aspects, provide a natural and eco-friendly alternative to synthetic preservatives [5].

Various studies have demonstrated the effectiveness of whey protein-based edible films and coatings in preserving cheese quality across different types of cheeses. Depending on the cheese type and formulation, these films act as protective barriers and improve chemical stability, microbial safety, and sensory characteristics.

Cheddar Cheese whey protein coatings enriched with antimicrobial agents were applied to Cheddar cheese to inhibit mold growth during storage. Han et al., (2014) [6] found that whey protein isolate films reduced mold formation by 85% over a 30-day storage period without adversely affecting the cheese's texture or flavor. The coatings maintained the cheese's firmness and nutty taste, which are critical for consumer acceptance.

Gouda Cheese edible films made from whey protein concentrate (WPC) and incorporated with oregano essential oil were applied to Gouda cheese study by [7] demonstrated a significant reduction in yeast and mold counts and improved lipid oxidation stability during 60 days of storage. Sensory analysis indicated that the coatings preserved the mild flavor and smooth texture of Gouda cheese.

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Whey protein films combined with thyme essential oil were applied to Parmesan cheese to mitigate moisture loss and microbial contamination during extended storage. The films significantly reduced weight loss due to dehydration retained the cheese's granular texture and enhanced its nutty aroma. These results highlight the films' potential for hard, aged cheeses [8].

Ultra-filtered cheese is a high-moisture cheese prone to spoilage. Incorporating rosemary and coriander extracts into the films extended the cheese's shelf life beyond 40 days by reducing microbial contamination and delaying lipid oxidation. Consumers reported minimal changes in the cheese's creamy texture and tangy flavor, indicating the coating's suitability for soft cheeses [9].

Camembert cheese was coated with a whey protein and beeswax film containing clove essential oil to inhibit mold growth during ripening. Results showed a 70% reduction in surface molds, with no negative impact on the ripening process or the cheese's characteristic creamy texture and earthy flavor [10].

Moringa Essential Oil: Extracted from the seeds of Moringa oleifera, this oil is rich in bioactive compounds like oleic acid, tocopherols, and flavonoids. Moringa oil exhibits strong antimicrobial activity against foodborne pathogens such as Escherichia coli and Staphylococcus aureus [11]. Its incorporation into edible films has demonstrated an enhanced ability to inhibit microbial growth while maintaining cheese's nutritional and sensory properties [12]. Jojoba Essential Oil: Derived from the seeds of Simmondsia chinensis, jojoba oil contains long-chain wax esters and exhibits remarkable antimicrobial and antioxidant activities. Studies have shown that jojoba oil can reduce oxidative stress in food products and inhibit spoilage microorganisms, making it an ideal candidate for edible films in cheese preservation [13]. Turmeric Essential Oil: Rich in curcuminoids and terpenoids, turmeric essential oil (Curcuma longa) is known for its strong antioxidant and antimicrobial properties. Incorporating turmeric EO into edible coatings protects cheese from lipid oxidation and imparts a mild, earthy aroma that complements the flavor profile of hard cheeses [14]. Pumpkin Essential Oil: Extracted from pumpkin seeds (Cucurbita pepo), this oil is rich in carotenoids, tocopherols, and phenolic compounds. It has demonstrated excellent antimicrobial effects, particularly against molds and yeasts, which are common spoilage organisms in cheese [15]. Pumpkin EO-enriched films can enhance the shelf life of cheese while contributing a subtle nutty aroma.

Similarly, Pumpkin powder enhances antioxidant stability, preserving the cheese's color and improved the moisture retention of the cheese, contributing to a creamier texture [16]. These essential oils have antimicrobial properties that make them effective against a broad spectrum of microorganisms. Jojoba EO in whey protein films has demonstrated inhibitory effects on Listeria monocytogenes, a key concern in cheese safety [13]. Meanwhile, Turmeric EO has shown efficacy against spoilage molds, ensuring extended shelf life and minimal waste [14]. The inclusion of EOs must be carefully optimized to avoid overpowering the cheese's natural flavor. Studies suggest that low concentrations of essential oils enhance the sensory attributes of cheeses by contributing subtle, complementary flavors. However, high concentrations can result in undesirable off-flavors. This study aims to evaluate the effect of whey protein-based edible films enriched with 1% different essential oils (Moringa, Jojoba, Turmeric, and Pumpkin oils) on the properties of Ras cheese. Specifically, the study examines the cheese's chemical, microbiological, and sensory attributes to assess the potential of these films in enhancing its quality and shelf life.

2. Material and Methods

Fresh whole Cow`s milk used in this study was obtained from the Faculty of Agriculture at Menoufia University without contact with the herd in Egypt. Local rennet 0.7N, "Elamel Elmasry, "was obtained by Ayman Haekel Company. Iodized normal salt, produced by El-Nasr Saline's Co, Alexandria, Egypt, was used. All used pure chemicals for measuring acidity, fat, and protein were obtained from El-Gomheria Chemical Company, Mansoura, Egypt. Commercial Pumpkin seed oil, Moringa oil, Turmeric oil, and Jojoba oil were purchased from Naqaa Company, a local market supplier.

Whey protein edible film preparation

The edible coating was prepared by following the method of **[17]**. In a 250 mL beaker, 5g Whey Protein Concentrate powder was used as the basis material for the active edible coating for Ras cheese, 10 ml of glycerol was added as a plasticizer, and 2g xanthan gum was used to increase viscosity. The pH was adjusted to 8.0 with 2 N NaOH. Then, solutions were heated to 90±2°C while being stirred continuously. After homogenizing for 30 minutes using a magnetic stirrer, the film solutions were filtered through a layer of cheesecloth. Pumpkin, Moringa, Curcumin, and Jojoba oil 0.5% were added to the film solutions as essential oil concentrations per film.

Manufacture of Ras Cheese

Ras cheese was prepared using standardized milk (3.5% fat) heated to 72°C momentary and then cooled immediately to 35°C, with rennet (2.5g/100kg) and active starter cultures of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* (2% w/w) added to achieve coagulation in 30–40 minutes. The coagulum was cut into chickpea-sized grains and stirred vigorously, and the vat temperature was gradually raised to 45°C over 40–50 minutes with gentle stirring. Once the curd settled, the whey (acidity ≈ 0.14%) was drained, and 1% (w/w) salt was sprinkled over the curd, which was then placed into cheesecloth-lined molds. Manual and light mechanical pressure were applied over 4 hours, followed by pressing for 18 hours. The cheese discs were turned over every day and rubbed with dry salt for 120 days at 14 °C ± 2 °C with humidity 80-85%. Cheeses were sampled and analyzed when fresh (5 days) and at monthly intervals up to four months. The whole experiment was duplicated **[18]**.

Cheese coating

Cheese wheels treatments were divided as follows: control (T0) without coating: (T1) Pumpkin essential oil 0.5%, (T2) Moringa essential oil 0.5%, (T3) Turmeric essential oil 0.5%, and (T4) Jojoba essential oil 0.5%. The coating was applied by dipping the cheese wheel for 2 min until all surfaces were covered, with the residual coating being allowed to drip off. The cheese was left until the coating was essentially dry. All cheese wheels were stored for ripening at 15.5ºC in a digital incubator for three months. Samples were analyzed at zero time and after one, two, three, and four months.

Chemical Analysis

The cheese surface layer was trimmed to a depth of 2 mm, and a representative inner sample (~25g) in triplicates was collected, ground, and stored in a sealed glass container for analysis. Cheese samples were analyzed for fat, total nitrogen (TN), soluble nitrogen (SN), titratable acidity, and moisture content according to **[19]**. Volatile fatty acids were determined using steam distillation, as described by **[20]**.

Microbiological Analysis

The poured plate method was used to enumerate microbial populations in cheese samples. One milliliter of appropriate serial dilutions was inoculated onto plates containing specific media. For fungal counts, Sabouraud Dextrose Agar (SDA) medium was used; approximately 15 ml of SDA at 50°C was poured into each plate, mixed thoroughly, and left to solidify. Plates were incubated at 25°C for 5 days, and the mean fungal colony count was recorded **[21]**. *Lactobacilli* were enumerated on MRS agar and incubated at 37°C for 48 hours under anaerobic conditions, following the method of **[22]**. *Streptococci* were counted using M17 agar, incubated at 37°C for 48 hours, as described by **[23]**. Coliform bacteria counts were determined using violet-red bile agar, following **[24]**. Samples were done in triplicates, and the mean colony counts from the plates were recorded for each microbial group.

Sensory evaluation

The organoleptic properties of resultant Ras cheese were assessed at the Department of Food Hygiene and Control, Menoufia University, Egypt, under the supervision and agreement of the Menoufia University Ethics Committee (MUFHE/F) and waived the need for approval. Twenty panelists from the staff members of Food Hygiene and Control, Faculty of Veterinary Medicine, Menoufia University, and staff members at the Department of Dairy Science and Technology, Faculty of Agriculture, Menoufia University (10 men and 10 women, aged 22 and 57), Informed consent was obtained from the participants to participate in the current study. The study's purpose and procedures were clearly explained to them, including any potential risks and benefits. Participants were informed of their right to withdraw from the study at any time without any consequence. The pantalets followed the method by **[25]**, considering that the maximum attainable scores were 50 points out of 100 for flavor, 40 points for body and texture, and 10 points for general appearance.

Statistical analysis

All samples were withdrawn twice with triplicate analysis. Results were analyzed using variance analysis (ANOVA) and Duncan's multiple mean comparisons. The level of significance was ($p \leq 0.05$), and all statistical analyses were performed using SPSS statistical software (version 16.0; SPSS Inc., Chicago, IL, USA). **[26].**

3. Results and Discussion

Fat Content and Dry Matter

The fat content across all treatments (Table 1) exhibited stability throughout the ripening period. For the control (T0), fat content increased slightly from 49.10% to 49.24% over 120 days. Coated samples also showed minimal changes, with the highest fat content observed in T3 (Turmeric oil) at 49.32% on day 120. The slower changes in fat content among coated samples highlight the protective effect of essential oil-enriched coatings in reducing oxidation and fat loss. Moringa (T2) and Jojoba (T4) coatings were particularly effective, maintaining fat levels comparable to T3, which may be attributed to their antioxidant properties **[13&14]**.

Nitrogen Fractions

The total nitrogen (TN) and soluble nitrogen (SN) contents, indicative of proteolysis during ripening, showed significant variations ($p < 0.05$) among treatments. T0 exhibited steady increases in SN/TN, reaching 32.46% by day 120. In contrast, T2 (Moringa oil) demonstrated the highest proteolysis (SN/TN: 42.78%), followed by T3 (Turmeric oil) at 36.36%. The accelerated proteolysis in T2 could enhance flavor development but necessitates careful balance to avoid textural degradation **[27]**. These findings align with **[3]**, who reported that whey protein coatings enriched with antimicrobial agents can modulate proteolytic activity.

Volatile Fatty Acids and Acidity

Total volatile fatty acids (TVFA) increased throughout ripening, with the highest accumulation in T2 (Moringa oil) at 105.81 ml NaOH/100g by day 120, indicating robust lipolytic activity. Acidity changes mirrored TVFA trends, with T2 showing the most pronounced increase (1.96%) compared to T0 (1.77%). This could be attributed to Moringa oil's stimulatory effect on lipolysis, potentially enhancing Ras cheese's characteristic nutty and tangy flavors **[11]**.

Moisture Content

Moisture levels decreased significantly ($p < 0.05$) across all samples, with T0 showing the highest loss (38.19%) by day 120. Coated samples, especially T2 (Moringa oil, 39.57%) and T4 (Jojoba oil, 38.28%), retained higher moisture content, emphasizing the role of coatings as semi-permeable barriers to water loss. These results are consistent with **[8]**, who observed reduced dehydration in coated Parmesan cheese.

Table (1): Chemical analysis of coated Ras cheese during ripening

		Fat /Dry Matter (%)			
Time (Days)	0	30	60	90	120
T0 (Control)	49.10^{d}±0.01	49.15^{d}±0.01	49.20^{c}±0.01	49.22^{c}±0.01	49.24^{c}±0.01
T1 (Pumkin)	49.12^{c}±0.01	49.17^{c}±0.01	49.21^{c}±0.01	49.19^{d}±0.01	49.13^{d}±0.01
T2 (Moringa)	49.17^{a}±0.01	49.21^{a}±0.01	49.20^{c}±0.01	49.26^{b}±0.01	49.29^{b}±0.01
T3(Turmeric)	49.15^{b}±0.01	49.21^{ab}±0	49.25^{a}±0.01	49.28^{a}±0.01	49.32^{a}±0.01
T4 (Jojoba)	49.15^{b}±0.01	49.19^{b}±0.01	49.23^{b}±0.01	49.25^{b}±0.01	49.28^{b}±0.01
		Total Nitrogen/ Dry Matter (%)			
T0 (Control)	5.72^{a}±0.01	5.74^{a}±0.01	5.75^{a}±0.01	5.77^{a}±0.01	5.80^{a}±0.01
T1 (Pumkin)	5.70b^{c}±0.01	5.72^{ab}±0.01	5.74^{ab}±0.01	5.76^{a}±0.01	5.77^{b}±0.01
T2 (Moringa)	5.71^{ab}±0.01	5.71^{b}±0.01	5.72^{bc}±0.01	5.74^{b}±0.01	5.75^{c}±0.01
T3(Turmeric)	5.69^{c}±0.01	5.71^{b}±0.01	5.72^{bc}±0.01	5.76^{a}±0.01	5.76^{bc}±0.01
T4 (Jojoba)	5.70^{bc}±0.01	5.71^{b}±0.01	5.73^{c}±0.01	5.74^{b}±0.01	5.77^{b}±0.01
		Soluble Nitrogen/Total Nitrogen (%)			
T0 (Control)	5.27^{ab}±0.01	16.98^{d}±0.05	18.76^{d}±0.02	26.93^{d}±0.02	32.46^{c}±0.01
T1 (Pumkin)	5.26^{b}±0.01	15.71^{e}±0.03	18.14^{e}±0.09	25.86^{e}±0.03	30.44^{d}±0.02
T2 (Moringa)	5.30^{a}±0.01	20.86^{a}±0.01	24.77^{a}±0.01	32.77^{a}±0.01	42.78^{a}±0.01
T3(Turmeric)	5.29^{ab}±0.01	18.46^{b}±0.01	22.07^{b}±0.04	29.56^{b}±0.01	36.36^{b}±0.01
T4 (Jojoba)	5.28^{ab}±0.01	17.85^{c}±0.03	20.06^{c}±0.03	28.25^{c}±0.01	36.34^{b}±0.01
		Total Volatile Fatty Acids (TVFA) (ml NaOH 0.1/100g)			
T0 (Control)	27.70^{d}±0.01	46.60^{d}±0.01	68.81^{d}±0.01	87.40^{d}±0.01	99.20^{d}±0.01
T1 (Pumkin)	27.59^{e}±0.01	45.60^{e}±0.01	68.01^{e}±0.01	86.52^{e}±0.02	98.01^{e}±0.01
T2 (Moringa)	28.06^{a}±0.03	53.11^{a}±0.01	72.81^{a}±0.01	95.20^{a}±0.01	105.81^{a}±0.01
T3(Turmeric)	28.00^{b}±0.01	50.10^{b}±0.01	70.80^{b}±0.01	92.19^{b}±0.01	103.71^{b}±0.01
T4 (Jojoba)	27.80^{c}±0.01	48.21^{c}±0.01	69.91^{c}±0.01	89.29^{c}±0.01	101.29^{c}±0.01
		Acidity			
T0 (Control)	0.4600^{a}±0.005	1.50^{c}±0.005	1.66^{d}±0	1.71^{d}±0.01	1.77^{d}±0.01
T1 (Pumkin)	0.4400^{ab}±0.005	1.42^{d}±0.01	1.61^{e}±0.01	1.71^{d}±0.01	1.72^{e}±0.01
T2 (Moringa)	0.4367^{b}±0.008	1.57^{a}±0.01	1.77^{a}±0.01	1.88^{a}±0.01	1.96^{a}±0.01
T3(Turmeric)	0.4433^{ab}±0.003	1.54^{b}±0.01	1.73^{b}±0.01	1.81^{b}±0.01	1.85^{b}±0.01
T4 (Jojoba)	0.4467^{ab}±0.006	1.50^{c}±0.01	1.71^{c}±0.01	1.76^{c}±0.01	1.81^{c}±0.01
		Moisture (%)			
T0 (Control)	41.59^{a}±0.01	40.43^{d}±0.01	39.22^{b}±0.11	38.33^{c}±0.17	38.19^{c}±0.02
T1 (Pumkin)	41.52^{a}±0.01	40.24^{e}±0.02	39.32^{b}±0.01	38.23^{c}±0.12	37.98^{d}±0.05
T2 (Moringa)	41.62^{a}±0.02	41.41^{a}±0.01	40.32^{a}±0.35	39.80^{a}±0.01	39.57^{a}±0.01
T3(Turmeric)	41.44^{a}±0.22	40.86^{b}±0.07	39.45^{b}±0.22	38.73^{b}±0.12	38.56^{b}±0.03
T4 (Jojoba)	41.54^{a}±0.02	40.55^{c}±0.03	39.50^{b}±0.01	38.72^{b}±0.01	38.28^{c}±0.03

T0: Control, **T1**: Cheese coat with **(Pumpkin Oil)**, **T2**: Cheese coat with **(Moringa Oil)**, **T3:** Cheese coat with **(Turmeric Oil), T4:** Cheese coat with **(Jojoba Oil).**

^{Abcde} Values in the same row having different superscripts differ significantly ($P < 0.05$)

Microbiological Quality of Ras Cheese

Lactobacilli sp. and *Streptococci sp. Counts*

Lactobacilli sp. counts varied significantly across treatments Table (2). T2 (Moringa oil) exhibited the highest counts (74×10^8 cfu/g) at day 90, supporting its role in promoting favorable microbial growth essential for ripening. *Streptococci sp.* counts followed similar trends, with T1 (Pumpkin oil) and T2 maintaining elevated levels compared to T0, suggesting enhanced microbial safety without compromising beneficial flora **[28]**.

Table (2): Microbiological quality of coated Ras cheese during ripening

Time (Days)	0	30	60	90	120
			Lactobacilli sp. (cfu/g)		
T0 (Control)	27 x10^6±0.01	40 x10^6±0.01^D	57x10^7±0.01^E	64x10^5±0.01^C	27 x10^4±0.01^C
T1 (Pumpkin)	27 x10^6±0.01	54 x10^7±0.01^C	74 x10^7±0.01^B	76x10^8±0.01^A	44 x10^7±0.01^A
T2 (Moringa)	27 x10^6±0.01	57 x10^7±0.01^C	82 x10^7±0.01^A	74x10^8±0.01^B	34 x10^7±0.01^B
T3(Turmeric)	27 x10^6±0.01	75 x10^6±0.01^B	67 x10^7±0.01^C	53x10^7±0.01^D	28 x10^6±0.01^C
T4 (Jojoba)	27 x10^6±0.01	87 x10^6±0.01^{AB}	63 x10^7±0.01^D	47x10^7±0.01^A	21 x10^6±0.01^D
			Streptococcus sp. count (cfu/g)		
T0 (Control)	24 x10^5±0.01	40x10^5±0.05^C	51x10^4±0.02^B	36x10^4±0.02^B	22 x10^4±0.01^B
T1 (Pumpkin)	24 x10^5±0.01	25x10^6±0.03^D	84 x10^5±0.09^A	60x10^5±0.03^A	28 x10^5±0.02^A
T2 (Moringa)	24 x10^5±0.01	17x10^6±0.01^E	62 x10^5±0.01^C	32x10^5±0.01^C	18 x10^5±001^C
T3(Turmeric)	24 x10^5±0.01	81x10^5±0.01^A	44 x10^5±0.04^D	26x10^5±0.01^D	14 x10^5±0.01^D
T4 (Jojoba)	24 x10^5±0.01	54x10^5±0.03^B	28 x10^5±0.03^E	18x10^5±0.01^E	6x10^5±0.01^E
			Yeast and molds (cfu/g)		
T0 (Control)	ND	4 x10^2 ±0.01	23 x10^3 ±0.01	87 x10^4±0.01^A	99 x10^5±0.01^A
T1 (Pumpkin)	ND	ND	ND	2 x10^1 ±0.02^C	8 x10^1±0.01^D
T2 (Moringa)	ND	ND	ND	5x10^1 ±0.01^C	19 x10^1±0.01^B
T3(Turmeric)	ND	ND	ND	3x10^2±0.01^C	14 x10^2±0.01^C
T4 (Jojoba)	ND	ND	ND	8 x10^2±0.01^B	21 x10^2±0.01^B
			Coliforms (cfu/g)		
T0 (Control)	ND	ND	ND	ND	ND
T1 (Pumpkin)	ND	ND	ND	ND	ND
T2 (Moringa)	ND	ND	ND	ND	ND
T3(Turmeric)	ND	ND	ND	ND	ND
T4 (Jojoba)	ND	ND	ND	ND	ND

T0: Control, **T1**: Cheese coat with **(Pumpkin Oil)**, **T2**: Cheese coat with **(Moringa Oil)**, **T3:** Cheese coat with **(Turmeric Oil), T4:** Cheese coat with **(Jojoba Oil).**

^{Abcde} Values in the same row having different superscripts differ significantly ($P < 0.05$)

Coliforms

Coliform counts were undetectable across all treatments throughout the 120-day ripening period. The absence of coliforms highlights the effectiveness of the essential oil-based whey protein coatings in maintaining Ras cheese's microbiological safety. This finding is consistent with previous studies **[13]**, which demonstrated the antimicrobial potential of jojoba and other essential oils in preventing contamination by coliform bacteria in dairy products.

Yeast and Mold Growth

Yeast and mold counts remained undetectable in all coated samples for the first 90 days, with minimal growth in T1 (Pumpkin oil) and T2 (Moringa oil) by day 120. These results underscore the antifungal efficacy of essential oils, particularly Moringa and Pumpkin, aligning with findings by **[29]**, who reported reduced spoilage in Feta cheese coated with rosemary oil films.

Sensory Evaluation of Ras Cheese

Flavor

Flavor scores Table (3) improved across all samples during ripening, with T1 (Pumpkin oil) achieving the highest score (48.00/50) by day 120. This enhancement could be attributed to the oil's contribution to lipid oxidation stability and flavor development. Similar trends were reported by **[7]** in Gouda cheese coated with oregano oil films.

Body, Texture, and Appearance

Body and texture scores Table (3) peaked in T1 and T3 (Turmeric oil) by day 120, highlighting their ability to preserve cheese firmness and smoothness. Appearance scores Table (3) also improved, particularly in T1 (8.66/10), reflecting the role of coatings in maintaining visual appeal. These findings align with **[11]**, who noted improved sensory attributes in coated Camembert cheese.

Table (3): Sensory Evaluation of coated Ras cheese during ripening

			Flavor (50)		
Time (Days)	0	30	60	90	120
T0 (Control)	35.00 ±0.38 ^{Bb}	43.00 ±0.38 ^{Ab}	44.33 ±0.38 ^{Abc}	44.50 ±0.38 ^{Ac}	45.00 ±0.38 ^{Ab}
T1 (Pumpkin)	37.33±0.38 ^{Ca}	44.83 ±0.38 ^{Ba}	47.33 ±0.38$^{A\ a}$	48.00 ±0.38^{Aa}	48.00 ±0.38^{Aa}
T2 (Moringa)	35.83 ±0.38 ^{Db}	42.83 ±0.38 ^{Cb}	44.83 ±0.38 ^{Bb}	45.83 ±0.38 ^{Ab}	45.83 ±0.38 ^{Ab}
T3(Turmeric)	34.83 ±0.38 ^{Eb}	43.83 ±0.38 ^{Dab}	44.67 ±0.38 ^{Cbc}	46.50 ±0.38 ^{Bb}	47.50 ±0.38 ^{Aa}
T4 (Jojoba)	34.84 ±0.38 ^{Db}	42.83 ±0.38 ^{Cb}	43.83 ±0.38 $^{B\ c}$	44.67 ±0.38 ^{Ac}	44.83 ±0.38 ^{Ab}
			Body and texture (40)		
T0 (Control)	32.50 ±0.30^{BCbc}	32.33 ±0.30^{Cd}	33.33 ±0.30^{ABc}	33.83 ±0.30^{Ac}	32.50 ±0.30^{BCc}
T1 (Pumkin)	33.50 ±0.30 ^{Da}	34.83 ±0.30 ^{Cab}	36.16 ±0.30 ^{Ba}	36.16 ±0.30 ^{Bb}	38.33 ±0.30 ^{Aa}
T2 (Moringa)	32.83 ±0.30 ^{Dab}	34.50 ±0.30 ^{Cb}	34.33 ±0.30 ^{Cbc}	35.66 ±0.30 ^{Bb}	37.50 ±0.30 ^{Aa}
T3(Turmeric)	31.83 ±0.30 ^{Ccd}	35.66 ±0.30 ^{Ba}	35.83 ±0.30 ^{Ba}	37.50 ±0.30 ^{Aa}	38.33 ±0.30 ^{Aa}
T4 (Jojoba)	31.50 ±0.30 ^{Cd}	33.50 ±0.30 ^{Bc}	34.66 ±0.30 ^{Ab}	35.66 ±0.30 ^{Ab}	35.66 ±0.30 ^{Ab}
			Appearance (10)		
T0 (Control)	6.00 ±0.28^{Ab}	5.66±0.28^{Ab}	5.66±0.28^{Ac}	6.66±0.28^{Ac}	6.5±0.28^{Ab}
T1 (Pumkin)	6.5±0.28 ^{Bab}	6.66±0.28 ^{Ba}	7.66±0.28 ^{Aa}	8.50±0.28 ^{Aa}	8.66±0.28 ^{Aa}
T2 (Moringa)	6.83±0.28 ^{Bab}	6.83±0.28 ^{Ba}	6.83±0.28 ^{Bab}	6.83±0.28 $^{B\ bc}$	7.66±0.28 ^{Aa}
T3(Turmeric)	7.00±0.28 ^{Ba}	7.00±0.28 ^{Ba}	7.50±0.28 ^{Ba}	7.83±0.28 ^{ABa}	7.00±0.28 ^{Ba}
T4 (Jojoba)	6.83±0.28 ^{ABab}	7.66±0.28 ^{Aa}	6.50±0.28 ^{Cbc}	7.66±0.28 ^{Aab}	7.66±0.28 ^{Aa}

T0: Control, **T1**: Cheese coat with **(Pumpkin Oil)**, **T2**: Cheese coat with **(Moringa Oil)**, **T3:** Cheese coat with **(Turmeric Oil), T4:** Cheese coat with **(Jojoba Oil).**

^{ABCDE} Values in the same row having different superscripts differ significantly (P < 0.05)

^{abcde} Values in the same column having different superscripts differ significantly (P < 0.05)

4. Conclusion

This study demonstrates the efficacy of whey protein-based edible coatings enriched with essential oils, particularly moringa and pumpkin oils, in preserving the quality, safety, and sensory appeal of Ras cheese during ripening. The coatings significantly reduced moisture loss, inhibited microbial spoilage (including coliforms, yeast, and mold), and enhanced key biochemical processes such as proteolysis and lipolysis. Moringa oil exhibited the most substantial impact on ripening acceleration and microbial balance, while pumpkin oil yielded the highest sensory scores for flavor, texture, and appearance.

These findings confirm that essential oil-enriched coatings serve as physical barriers and bioactive modulators of cheese maturation. This approach offers a promising natural alternative to synthetic preservatives, aligning with consumer demand for clean-label, eco-friendly dairy products.

Future research should explore optimizing oil concentrations and combining different essential oils to balance microbial inhibition with sensory compatibility. Broader application of this technology across various cheese types and dairy systems is warranted to support sustainable innovations in food preservation.

5. Conflicts of interest

The authors declare no competing interests.

6. Formatting of funding sources
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