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Enhancing the Quality and Safety of Ras Cheese Using an Active Edible Film Based on Potato Peel Powder and Turmeric

[1]Wafaa M. Salama, [1]Waheed A. Ragb, [2]Entsar S. Abdou & [*1]Atiat S. Dosuky

[1]Dairy Technology Research Department, Food Technology Research Institute, Agricultural Research Center, Giza, 12613, Egypt

[2]Food Engineering and Packaging Department, Food Technology Research Institute, Agriculture Research Center, Giza, 12613, Egypt

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ABSTRACT

This study aimed to develop and evaluate an active edible film formulated from potato peel powder (PPP) and turmeric to enhance the quality, safety, and shelf life of Ras cheese. Films containing 1%, 2%, and 3% PPP with 0.5% turmeric were prepared and applied as coatings on cheese wheels. The rheological, mechanical, and barrier properties of the films were analyzed, along with their effects on the physicochemical, microbiological, textural, and sensory properties of the cheese during a 90 day ripening period. Results showed that increasing the concentration of PPP improved the film's tensile strength and significantly reduced water vapor transmission. A gradual and significant increase in soluble nitrogen percentage (SN) was observed in both the control and all treated samples as the storage period progressed. Coated cheeses retained more moisture, exhibited reduced acidity and proteolysis, and showed significantly lower microbial counts, especially for molds and yeasts. The antimicrobial activity was attributed to the high phenolic content of PPP and the curcumin in turmeric. Textural parameters such as cohesiveness, springiness, and chewiness improved, particularly in the cheese coated with the 2% PPP film. Sensory evaluation revealed that coated samples especially those with 2% PPP had superior flavor, texture, and appearance compared to the uncoated control.

1. Introduction

Ras cheese is the most well-known hard cheese produced in Egypt and is comparable to Greek kefalotyri cheese (Abou-Donia, 2002). It is typically made from raw cow's milk or a mixture of cow and buffalo milk and is ripened at 12 to 15 °C and 80% relative humidity for a minimum of three months. One of the most common challenges in Ras cheese production is the growth of mold on the surface and within cracks during ripening. Fungal contamination not only leads to economic losses and quality deterioration but also negatively affects the cheese's aesthetic value and shelf life. Mold growth reduces cheese yield due to the need for surface removal, decreases consumer appeal due to off flavors, and poses health risks due to the potential presence of aflatoxins. Mycotoxins, naturally produced by some fungi, are toxic and can be harmful or even fatal to humans and animals (Bennett and Klich, 2003). Various strategies have been explored to prevent mold formation on cheese, including waxing, radiation, treatment with preservatives such as natamycin and potassium sorbate, and application of edible coatings or films (Kebary et al., 2011, El-Sisi et al., 2015). Recently, researchers have turned to innovative and eco-friendly materials for developing edible films that can inhibit fungal growth on food surfaces. One such promising material is potato peels (PP), which are abundant, inexpensive, and environmentally friendly byproducts of the potato processing industry. Potato peels are rich in starch, cellulose, and phenolic compounds, which contribute to their film-forming capabilities and antioxidant activity. Potato peels naturally contain antifungal compounds, such as phenolics and essential oils, which have been shown to inhibit various fungi commonly associated with cheese spoilage.

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*Corresponding Author
Email: atiat_2@yahoo.com

According to Gebrechristos and Chen Gebrechristos and Chen (2018), potato peel extracts possess antimicrobial activity against both bacteria and fungi. Gebrechristos et al. (2020) also reported that combining potato peel extract with potato starch yields an active film with antioxidant and antibacterial properties, offering a viable option for active food packaging. Silva -Beltrán et al. (2017) found that potato peels are rich in phenolic compounds that provide antioxidant and antibacterial benefits to human health. Additionally, when used in coatings or film production, potato peel powder exhibits good barrier, mechanical, functional, and antimicrobial properties. These attributes make it a valuable component for sustainable food packaging solutions, contributing to waste reduction and promoting a circular economy in the food industry. Grunert (2018) also highlighted the potential of potato waste, particularly its phenolic content, for use in food preservation and pharmaceutical applications. Incorporating potato peel extracts or powders into edible films offers a natural and effective approach to preventing fungal growth on food surfaces. Borah et al., (2017) and Elfadaly et al. (2023) utilized a combination of potato and mango peel extracts with whey proteins as a biopolymer to enhance the antioxidant capacity of processed cheese, extend its shelf life, and reduce microbial and spore counts. Food by-products, whether used individually or in combination for biodegradable packaging, predominantly degrade into carbon dioxide and water, making them an environmentally friendly option for food preservation (Flores et al., 2017; Vargas et al., 2008). Edible coatings can also be infused with food additives such as organic acids, enzymes, bacteriocins, fungicides, natural extracts, and vitamins to inhibit pathogen growth, improve shelf life, and enhance sensory quality (Appendini and Hotchkiss, 2002). In this study, turmeric was combined with potato peel powder to formulate an edible film, due to turmeric's strong antifungal and antimicrobial properties. Turmeric is a vibrant yellow spice derived from the *Curcuma longa* plant. Its active compound, curcumin a polyphenol is responsible for its antifungal activity. Traditionally, turmeric has been used to treat wounds, burns, liver and gastrointestinal disorders, respiratory conditions (such as asthma, cough, and sinusitis), anorexia, and rheumatism. It also exhibits antiseptic, antibacterial, and anti-inflammatory properties (Nair, 2019). Today, turmeric and curcumin (classified as E100) are widely used as food additives for flavoring, coloring, and preservation in products like margarine, cheese, butter, pasta, and beverages (Nair, 2019). Moreover, incorporating curcumin into edible films can enhance their functionality by providing antimicrobial and antioxidant protection. Xie et al. (2020) developed a biodegradable film using potato peels, curcumin as an antioxidant, and bacterial cellulose as a reinforcing agent. To the best of our knowledge, no previous research has investigated the use of potato peel powder (PPP) in combination with turmeric to create an active edible film for coating Ras cheese. Therefore, this study aimed to evaluate the effect of such a coating on the quality, safety, and shelf life of Ras cheese, focusing on the mechanical and barrier properties of the film.

2. Materials and Methods

Materials

Fresh cow's milk (3% fat) and buffalo milk (6% fat) were obtained from the Faculty of Agriculture, Cairo University, Egypt. Potato peels (variety "Agria") were collected from a local producer in Giza Governorate, Egypt. The starter culture, consisting of *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (1:1), was supplied by Chr. Hansen's Laboratory (Copenhagen, Denmark). Rennet powder (Hanelase) was also obtained from Chr. Hansen's Laboratory. Fine cooking salt, produced by El-Nasr Salines Company, was purchased from the local market.

Preparation and Characterization of Potato Peel Powder

Fresh potato peels were washed with tap water, then air-dried at 40 °C in a ventilated oven for 48 hours. The dried peels were ground into fine powder and sieved through a 60-mesh screen. The resulting powder was packed in polyethylene bags, stored in refrigeration, and used within 30 days. The composition of the powder was analyzed and found to contain moisture (4.2%), Fat (0.48%), Protein (16.86%), Ash

(8.56%), Total phenolic content (25.87mg GAE/g), Antioxidant activity (48.56%).

Preparation of Edible Films

Potato peel powder (PPP) was used to prepare biopolymer films. Three concentrations 1%, 2%, and 3% (w/v) were tested. For each film, PPP (1, 2, or 3g) was mixed with 100 mL of distilled water using a homogenizer (JS Research Inc., Korea) at 25,000 rpm for 5 minutes. To reduce brittleness, glycerol (1.5 mL/100 mL solution) was added as a plasticizer.

Additional film components were incorporated sequentially, each followed by homogenization at 25,000 rpm for 5 minutes:

- Turmeric powder (0.5%)
- Lecithin (0.5%)
- Whey protein (0.5%)

The final film forming mixture was heated using a microwave for 1.5 minutes and subsequently used to coat the Ras cheese.

Edible Film Characterization

Rheological Properties

The rheological behavior of the film dispersions was assessed at room temperature using a Brookfield Digital Rheometer (Model HA DVIII Ultra, Brookfield Engineering Laboratories, Inc.). A SC4-21 spindle was used, and each dispersion was tested separately using a small sample adapter.

Mechanical Properties and Water Vapor Transmission Rate (WVTR)

Mechanical properties of the films were measured using a Brookfield Texture Analyzer CT3 (USA) equipped with a TA-AACC3 probe and TA-FSF fixture. The testing parameters were: trigger force of 10 g, target distance of 20mm, and test speed of 0.5mm/s. WVTR was determined using the gravimetric method based on ASTM E96 (desiccant method). Circular film samples (5cm diameter, 0.3mm average thickness, defect-free) were placed over cups containing calcium chloride ($CaCl_2$) and sealed. The cups were incubated for 10 days at 25°C and 75% relative humidity (maintained using a saturated NaCl solution). Daily weight gains were recorded, and WVTR was calculated (g/cm²/day) by plotting the weight increment over time and dividing by the film area (Abd El-Rehim et al., 2018).

Manufacture of Ras Cheese Coated with Potato Peel Film

The Ras cheese manufacturing process was adapted from Hofi et al. (1970), with modifications to include film coating. A blend of 7 kg cow's milk and 3 kg buffalo milk was standardized to approximately 4% fat, pasteurized at 65 °C for 30 minutes, and cooled to 35 °C. Then, 2% yogurt starter culture (*L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus*, 1:1) was added. After dry salting, the cheese wheels were divided into four treatments:

- Control: Uncoated cheese
- T1: Cheese coated with 1% PPP edible film
- T2: Cheese coated with 2% PPP edible film
- T3: Cheese coated with 3% PPP edible film

Two wheels were prepared for each treatment: one was used to study mold growth and weight loss, while the other was used for chemical, microbiological, textural, and sensory analyses. All cheeses were stored at 15°C±2 for three months. Analyses were conducted at the beginning (fresh) and then monthly over the storage period. A graphical abstract (Figure 1) illustrated the production and coating steps of Ras cheese, beginning after the salting stage and continuing through storage. The entire experiment was repeated three times.

Methods of analysis

Analytical Methods

Cheese samples were analyzed for total nitrogen (T.N), soluble nitrogen (S.N), moisture, titratable acidity (T.A), fat, and ash according to the standard methods outlined by AOAC (2012). The pH of cheese samples was measured using a pH meter (HANNA, Model 211).

Extraction of Phenolic Compounds

Phenolic compounds were extracted by mixing 2g of potato peel powder with 30mL of an aqueous methanolic solution (70:30 v/v) at ambient temperature. The mixture was stirred for 24 hours in the dark to prevent photo-oxidative degradation of polyphenols. After centrifugation at 4000 rpm for 20 minutes, the supernatant was collected. The residue was then re-extracted with another 30mL of the same solvent, and both supernatants were combined. This combined extract was used to determine antioxidant activity (AOA) and total phenolic content (TPC). TPC was measured according to the method described by El-Falleh et al. (2009),and results were expressed in mg gallic acid equivalents per gram (mg GAE/g). AOA was determined using the DPPH radical scavenging assay as described by Okonogi et al. (2007).

Texture Profile Analysis (TPA)

The texture profile of Ras cheese was evaluated using an Instron Universal Testing Machine (Model 1195, Stable Micro Systems Ltd., Godalming, UK) equipped with Dimension Software. The analysis was conducted at 23 °C, following the method described by Bourne (1978).

Weight Loss Estimation

Weight loss was measured monthly during the ripening period for each cheese wheel. It was calculated as a percentage of the initial weight using the following formula:

$$\text{Weight loss (\%)} = \frac{\text{(initial weight)} - \text{(final weight)}}{\text{(initial weight)}} \times 100$$

Microbiological and Sensory Evaluation

Microbiological analyses were conducted following standard procedures for the examination of dairy products (Marshall, 1992). The following microbial groups were assessed: Total bacterial count using nutrient agar and Yeasts and molds count using potato dextrose agar.

Sensory Evaluation

Sensory evaluation of Ras cheese samples was performed by a trained panel of 15 members (6 males and 9 females) from the Dairy Technology Research Department, Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. The panelists ranged in age from 35 to 65 years. Cheese samples were evaluated for: Flavor (50 points), Body and texture (40 points) and Appearance (10 points). The scoring system was based on the method described by Hofi et al. (1970). Samples (25g each) were randomly coded with three-digit numbers, placed in foam dishes, and served at 30°C for evaluation.

Statistical Analysis

All data were analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) software (2008). The least significant difference (LSD) test was applied to determine significant differences between treatment means at a significance level of $P \leq 0.05$.

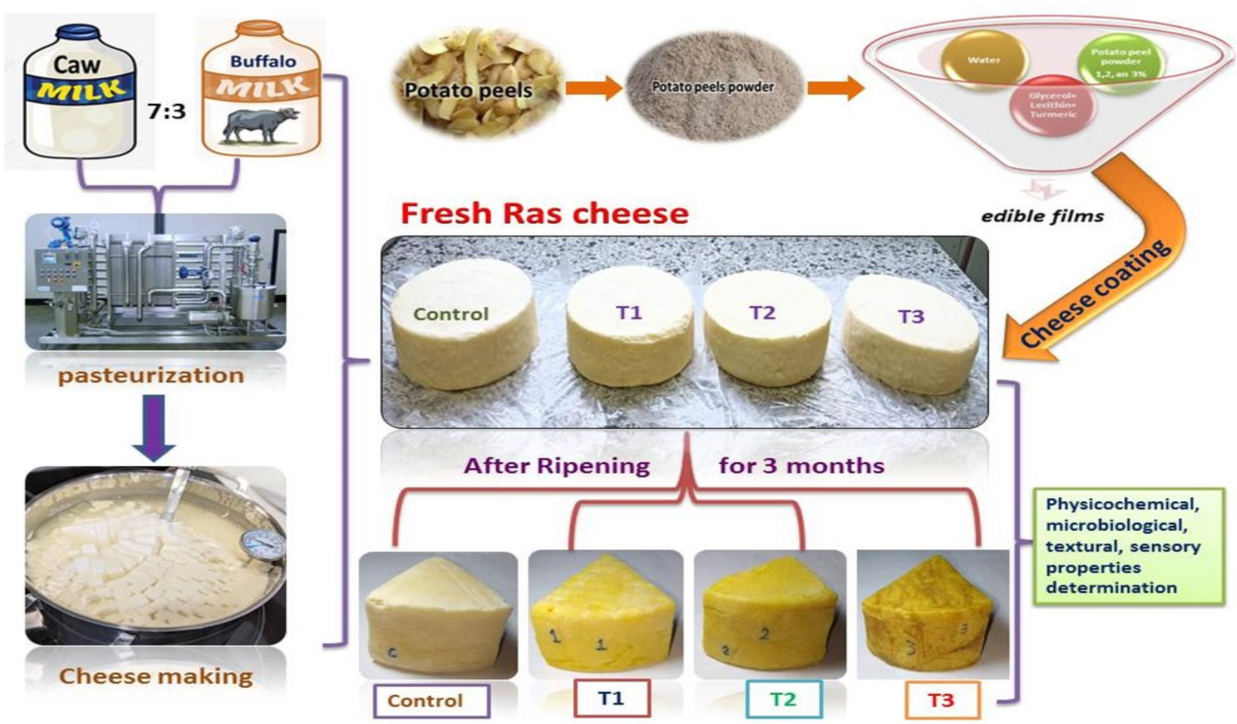


Figure 1. A graphical abstract illustrates the production of edible film-coated Ras cheese using different proportions of potato peels

3. Result and discussion

Rheological properties of coating dispersions

The flow behavior of coating solutions prepared with varying concentrations of potato peel powder (PPP) (1%, 2%, and 3%) was analyzed to assess their suitability for use in edible film formation. All coating dispersions exhibited non-Newtonian pseudoplastic behavior (n < 1), as shown in Figure 2 and described by the power low model:

$$\tau = k\gamma^{n}$$

Where, τ is the shear stress (Pa), γ is the shear rate (s^{-1})

Figure 3 demonstrates the inverse relationship between shear rate and apparent viscosity in all samples. This shear-thinning behavior is desirable in coating applications, as it facilitates ease of application at high shear (e.g., brushing, spraying), while ensuring good film-forming ability at rest due to recovery of viscosity. The increased viscosity at higher PPP concentrations can be attributed to the water-binding and gelling properties of dietary fibers and pectin in the potato peels. These components contribute to a more structured and cohesive film matrix, beneficial for barrier performance and mechanical strength. Overall, the rheological profile of the dispersions suggests that 2% PPP provides an optimal balance between manageable viscosity and desirable film-forming properties for coating cheese surfaces.

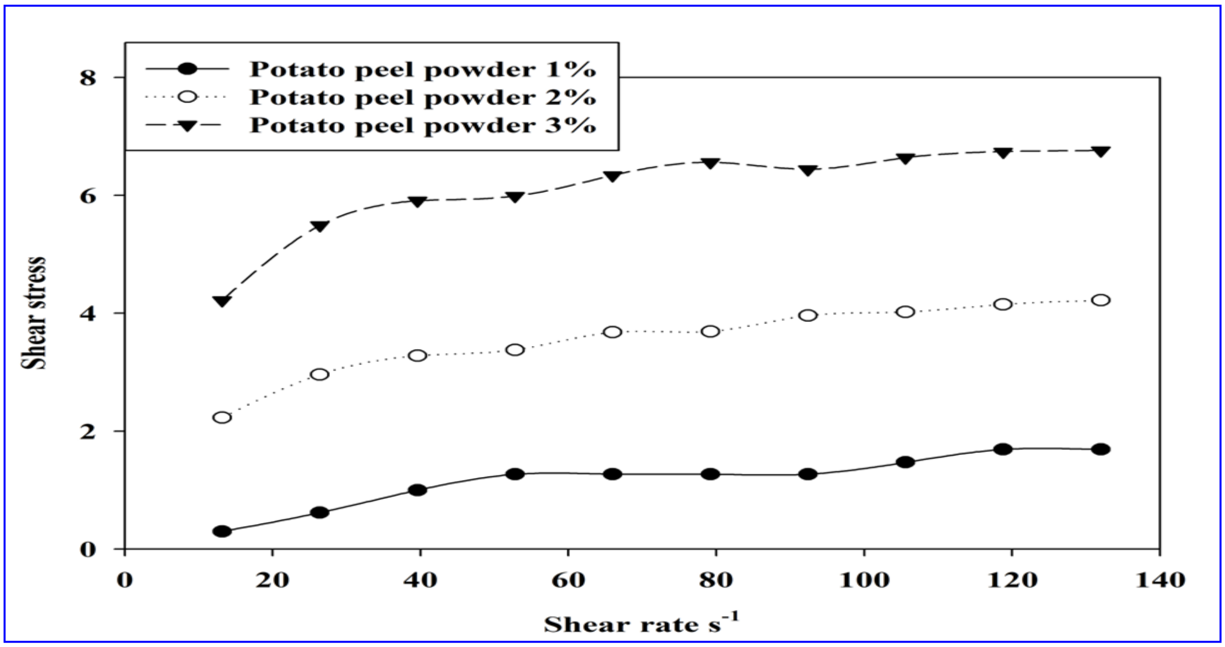


Figure 2. Effect of shear rate on shear stress of potato peel powder

Table 1 presents the rheological parameters derived from the Power Law model for coating dispersions containing 1%, 2%, and 3% potato peel powder (PPP). The flow behavior index (n) values were all less than 1, confirming pseudoplastic behavior across all formulations. Notably, n decreased significantly from 0.6968 to 0.1869 as PPP concentration increased, indicating stronger shear-thinning characteristics at higher fiber content. The consistency index (k) showed a substantial increase, rising from 0.0621 for the 1% PPP dispersion to 2.8194 for the 3% formulation. This reflects a marked increase in the apparent viscosity and structural strength of dispersion, likely due to the higher content of pectin, starch, and insoluble fiber in the potato peel powder. The coefficient of determination (R^2) ranged from 0.91 to 0.97, indicating a strong fit of the model to the experimental data. These results suggest that 2–3% PPP formulations offer suitable rheological properties for forming stable, cohesive edible coatings.

Table 1. Parameters of power law model flow behaviour index (n), consistency index (k) and coefficient of determination (R^2) for potato peel powder-based coating dispersions coating dispersions.

Sample	Consistency index (K)	Flow behaviour index (n)	R^2
1 %	0.0621	0.6968	0.9189
2 %	1.1995	0.2619	0.9742
3 %	2.8194	0.1869	0.9129

Effect of shear rate on the apparent viscosity of potato peels coating dispersions

Figure 3 shows the apparent viscosity values (Pa·s) versus shear rate (s^{-1}) for all coating dispersions. As illustrated, the viscosity is strongly dependent on shear rate. For all prepared coating dispersions, viscosity decreased as the shear rate increased. This decrease can be attributed to the breakdown of the colloidal structure at higher shear rates (Pal, 1999). The viscosity–shear rate relationship is fitted to the following equation:

$$\mu = k\gamma^{(n-1)}$$

Where: μ is apparent viscosity (Pa.s.), γ shear rate s^{-1}. As also shown in Figure 3, the viscosity of the coating dispersions increases significantly with the increasing percentage of potato peels. This may be due to the presence of soluble fibers such as pectin and gums in potato peels, which have high water-holding capacity, strong hydration ability, and the potential to form viscous suspensions (Kaur et al., 2022).

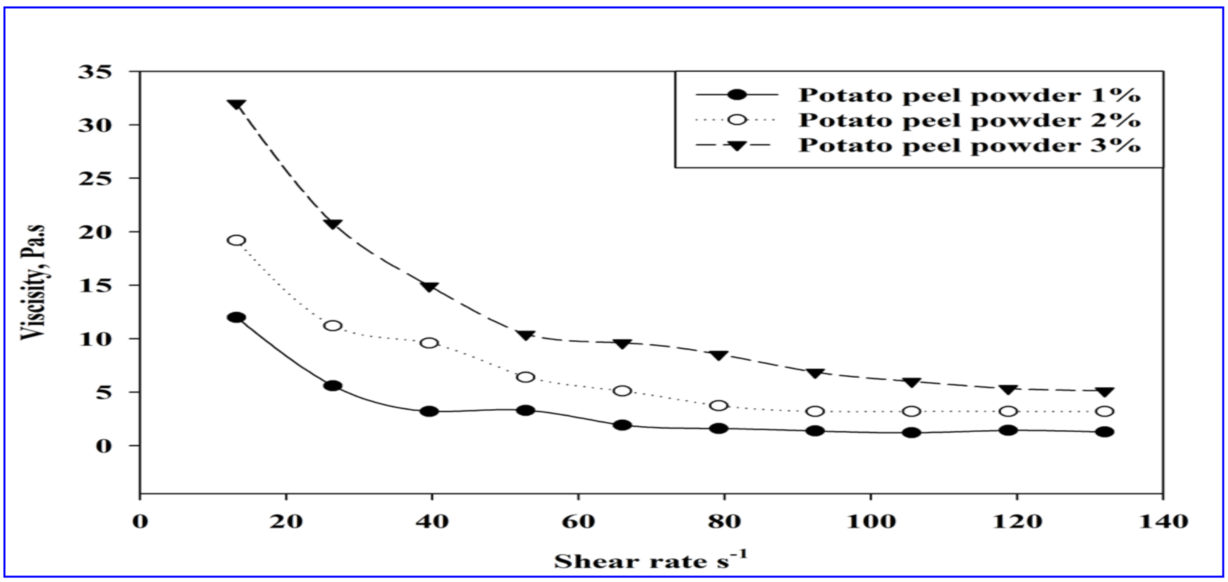


Figure 3. Apparent Viscosity of peel powder-based coating dispersions at different shear rates

Mechanical properties of potato peel films

The mechanical properties of films are critical to ensuring the integrity of packaging materials (Wang et. al., 2009). As presented in Table 2, the mechanical performance of the edible films showed a clear trend with increasing concentrations of potato peel powder (PPP). Tensile strength significantly increased from 1.08MPa at 1% PPP to 2.10MPa at 3% PPP ($P \leq 0.05$), indicating the development of a denser and more cohesive biopolymer network due to the higher content of starch and dietary fiber. Conversely, elongation at break decreased markedly from 13.4% to 2.7%, suggesting reduced flexibility and increased brittleness, which may impact the film's handling and application during cheese coating. The chemical composition of film-forming components has a substantial effect on the final properties of the resulting films. According to Purba et al. (2017) potato peel powder contains considerable amounts of starch and pectin. The size distribution of composite components in the potato peel-based films influences their mechanical properties.

Homogenization plays a vital role in modifying the size distribution of dispersed biopolymers, altering biopolymer particle structure, and generating more homogeneous aggregates. These changes can affect particle surface qualities and the overall organization of the biopolymer matrix, potentially altering the film's tensile characteristics. As shown in Table 2, elongation at break (%) significantly decreased with increasing PPP content in the composite films. This could be attributed to a higher pectin concentration, which negatively affects the film's elongation capacity. Increased pectin levels are associated with enhanced load-bearing capacity and stiffness, but also a reduction in flexibility and extensibility (Purba et al. 2017).

Water Vapor Permeability for edible films

Water vapor permeability (WVP) is a crucial factor for evaluating edible films, as one of their primary functions is to reduce moisture transfer between the food and its environment (Yan et al., 2022). The water vapor transmission rate (WVTR) declined from 20.85×10^{-3} to 14.06×10^{-3} g/cm²/day with increasing PPP concentrations, indicating improved barrier properties. These enhancements contributed to better moisture retention in the coated cheese samples. Although the observed trends are consistent and scientifically valid, further analysis would be beneficial to correlate these mechanical findings with other important film characteristics such as film thickness, adhesion to cheese surfaces, and behavior during application and storage. According to McHugh et al. (1994), the internal polymer structure within the film matrix greatly influences water vapor transmission. This may also be due to the presence of gelatinized starch in the potato peels, which likely contributed to tighter molecular structures and reduced molecular mobility, even after plasticization. These tighter structures could provide greater resistance to moisture transfer.

Table 2. Parameters of Tensile strength (MPa), Elongation (%) and Water vapour transmission rate (g/cm^2/day) for potato peels coating dispersions.

Sample	Tensile strength (MPa)	Elongation (%)	WVTR (g/cm^2/day)
1%	1.080	13.40	20.85×10^{-3}
2%	1.470	9.03	17.93×10^{-3}
3%	2.100	2.70	14.06×10^{-3}

Physicochemical analysis of Ras cheese

The data presented in Table 3 illustrate the chemical composition of uncoated and coated Ras cheese treatments with varying concentrations of potato peel powder (PPP) during storage at 15±2°C for up to 90 days. Coating Ras cheese with different levels of potato peel powder led to a significant increase in moisture content compared to the uncoated control. This effect is attributed to the barrier properties of PPP, which reduce water evaporation from the cheese surface (Xie et al., 2020). Among the treatments, moisture content increased proportionally with the concentration of PPP in the film. The incorporation of PPP enhanced resistance to water vapor transmission, thereby improving the protective characteristics of the edible films (as shown in Table 2).Throughout the 90-day storage period at 15±2°C, moisture content gradually decreased in all treatments, including the control. This reduction is likely due to natural water loss via evaporation. However, the rate of moisture loss in coated cheese samples was notably lower than in the uncoated control, confirming the effectiveness of the PPP-based films in retaining moisture, these findings are consistent with those reported by El-Sisi et al. (2015). Additionally, Table 3 reveals that the fat, protein, and ash contents were relatively lower in all coated cheese treatments compared to the control. The uncoated cheese exhibited the highest values for these components. This observation can be explained by the greater moisture loss in the control sample, which led to an increase in total solids and, consequently, higher concentrations of fat, protein, and ash. Over the storage period, an increase in fat, protein, and ash content was observed in all treatments, including the control, with levels rising progressively with storage time. These results align with those reported by Ibrahim et al. (2023). As shown in Figure 4, the rate of weight loss in coated cheese samples was lower than in the uncoated control. Furthermore, the higher the concentration of PPP in the edible film, the lower the observed weight loss (Figure 4). This can be attributed to the reduced water evaporation in the coated samples. Moreover, the increased PPP content in the film likely enhanced water-binding capacity, as potato peels are rich in dietary fiber and other hydrophilic components that retain moisture, thereby reducing weight loss during storage. This is supported by Jeddou et al. (2016), who reported that potato peels are a valuable source of dietary fiber.

Table 3. Chemical composition (%) of Ras cheese coated with potato peel based edible film when fresh and during ripening period at 15±2ºC for 90 days

Parameter (%)	Storage period (days)	Treatments*			
		C	T_1	T_2	T_3
Moisture	Zero	37.58^{ABc}	37.61^{Abc}	37.65^{Ab}	37.77^{Aa}
	30	34.44^{Ci}	35.53^{Bf}	35.94^{Ae}	36.02^{Ad}
	60	31.55^{Dn}	33.73^{Cj}	34.54^{Bh}	34.71^{Ag}
	90	29.72^{Do}	32.13^{Cm}	33.29^{Bl}	33.48^{Ak}
Fat	Zero	28.70^{Al}	28.51^{Bm}	28.48^{Cm}	28.50^{Bm}
	30	31.60^{Ah}	31.39^{Bi}	30.84^{Ci}	29.85^{Dk}
	60	33.85^{Ac}	32.91^{Bf}	32.79^{Cg}	31.35^{Dcd}
	90	34.63^{Aa}	34.08^{Bb}	33.51^{Cd}	33.18^{De}
Protein	Zero	23.37^{Al}	23.16^{Bmn}	23.23^{ABm}	23.09^{Cn}
	30	25.76^{Ah}	25.67^{Ai}	25.54^{Bj}	25.32^{Ck}
	60	26.96^{Ac}	26.13^{Bf}	25.92^{Cg}	25.75^{Dh}
	90	28.45^{Aa}	27.25^{Bb}	26.83^{Cd}	26.64^{De}
Ash	Zero	5.46^{Ah}	5.31^{Big}	5.35^{Bi}	5.29^{Cj}
	30	5.88^{Ad}	5.62^{Bg}	5.59^{Cg}	5.48^{Dh}
	60	6.12^{Ab}	5.93^{Bd}	5.70^{Cf}	5.78^{De}
	90	6.20^{Aa}	6.03^{Bc}	5.91^{Cd}	5.90^{Cd}

*** C, T_1, T_2, T_3: Ras cheese samples coated with 0, 1, 2 and 3% potato peel powder film respectively.**
A,B,C : Means with the same letter among treatments are not significantly different (P≤0.05)
a,b,c : Means with the same letter during storage period are not significantly different (P≤0.05)

Figure 5 (A, B) illustrates the changes in titratable acidity and pH values of Ras cheese coated with potato peel powder (PPP), both in fresh samples and throughout the 3-month storage period at 15±2°C. The control cheese (uncoated) exhibited the highest acidity values at the beginning and throughout the ripening period. In contrast, the coated treatments particularly T2 and T3 demonstrated a slower increase in acidity and more stable pH values. This suggests the potential antimicrobial effect of the bioactive components present in the edible films. Turmeric contains curcumin, a well-documented natural antimicrobial agent, while potato peel powder is rich in phenolic compounds such as chlorogenic acid. These compounds likely inhibited the growth and metabolic activity of lactic acid bacteria, thereby reducing acid production during ripening. Although the incorporation of PPP into the edible films increased the moisture content of the cheese, which might typically promote microbial activity and acid development, the acidity levels in coated samples remained lower than in the control. This reduction is likely attributed to the high phenolic content of potato peel powder, which exerts antimicrobial effects (Gebrechristos et al., 2020), and the presence of curcumin from turmeric, known for its broad-spectrum antimicrobial properties (Kapoor, 1997). Among the coated treatments, cheese coated with 1% PPP (T1) exhibited the highest acidity values, while the 3% PPP treatment (T3) had the lowest. This trend can be explained by the increasing antimicrobial activity associated with higher levels of PPP in the edible film. Notably, the total phenolic content in the potato peel powder was 25.87mg GAE/g, which likely contributed to this effect. As expected, the titratable acidity of all cheese samples including the control increased progressively over the 90-day ripening period. This rise in acidity is associated with lactose fermentation by microbial populations. Correspondingly, pH values decreased over time, showing an inverse relationship with acidity. These results are consistent with findings reported by El-Sisi et al. (2015).

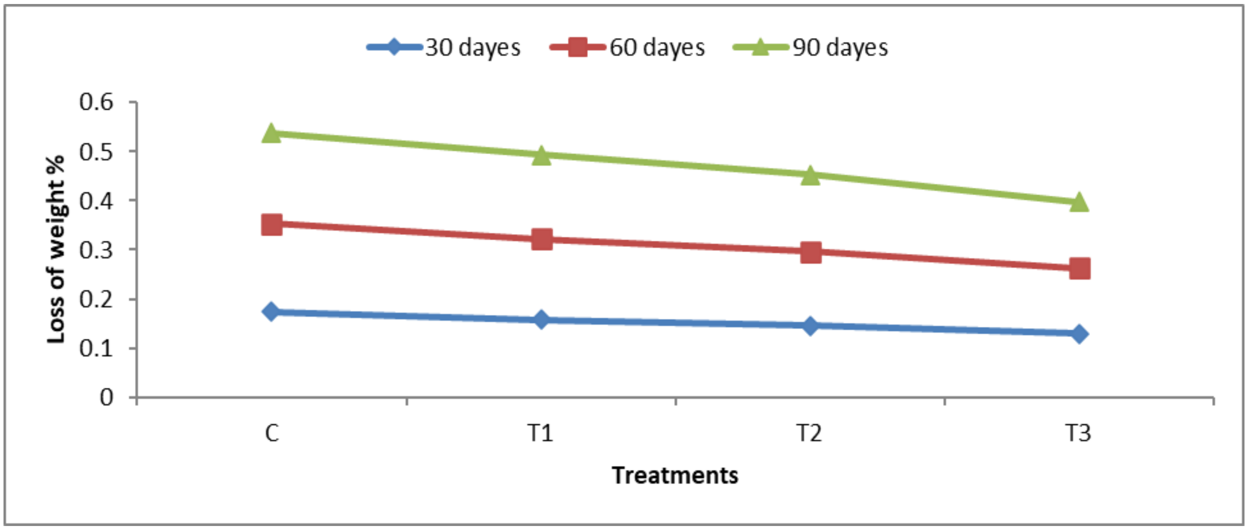
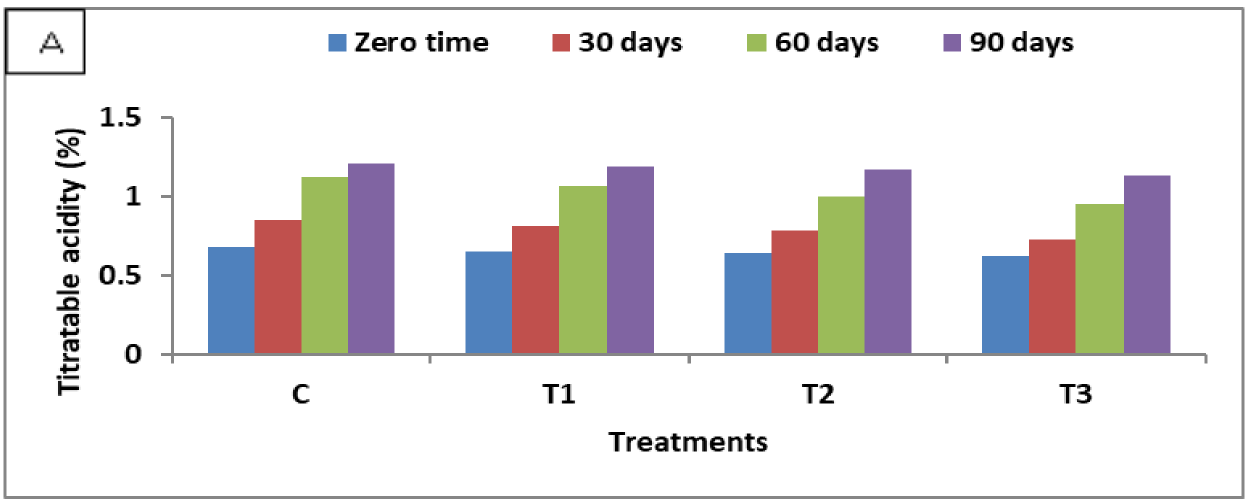


Figure 4. Loss of weight (%) of Ras cheese coated with potato peel based edible film when fresh and during ripening period at 15±2ºC for 90 days



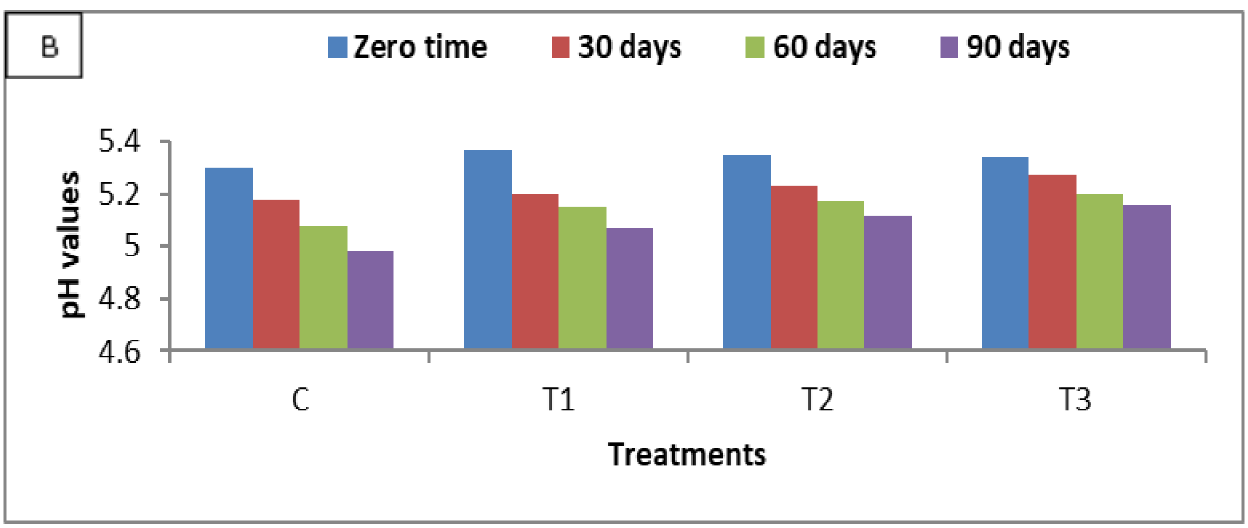


Figure 5. Titratable acidity (A) and pH values(B) of Ras cheese coated with potato peel based edible film when fresh and during ripening period at 15±2ºC for 90 days

Changes in soluble nitrogen (SN%) a key indicator of proteolysis and cheese ripening are presented in Figure 6. On day 0, SN% values were slightly higher in the coated cheese samples compared to the uncoated control. This may be attributed to initial enzymatic interactions with the components of the edible coating matrix. Over the 90-day ripening period, however, the rate of increase in SN% was significantly higher in the control cheese than in the coated treatments. This suggests that proteolytic activity progressed more slowly in the coated samples, a trend consistent with findings by Ibrahim et al., (2023). The degree of proteolysis in cheese is influenced by various factors, including moisture content, storage temperature, acidity, and the presence of bioactive compounds. The reduced rate of proteolysis observed in coated cheeses may be due to a lower microbial load and more stable pH values, both of which help to limit enzymatic degradation of proteins. Overall, all treatments showed a gradual increase in SN% throughout the ripening period, in line with increasing acidity levels that enhance enzyme activity during cheese maturation (Fox, 1989).

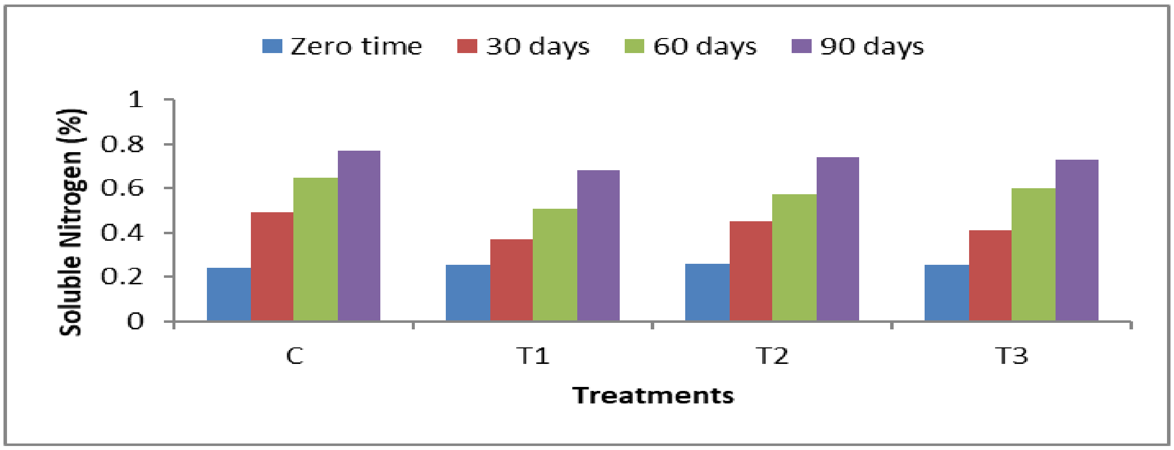


Figure 6. Soluble nitrogen (%) of Ras cheese coated with potato peel based edible film when fresh and during ripening period at 15±2ºC for 90 days.

Microbiological analysis of Ras cheese

Microbiological changes in uncoated and coated Ras cheese treatments with potato peel powder during storage at 15± 2°C for up to 90 days are presented in Table 4. The data show that the total bacterial count (TBC) in coated cheese samples was consistently lower than that of the uncoated control throughout the storage period. This reduction is likely due to the lower oxygen availability in coated cheeses compared to uncoated ones. Cerqueira et al. (2010) reported that chitosan coatings reduce the partial pressure of oxygen (pO_2), limiting microbial growth. Similarly, Elfadaly et al., (2023) observed that processed cheese samples coated with potato and mango peel extracts had lower bacterial counts than uncoated controls. These findings are in agreement with studies by Albishi et al., (2013) and Friedman et al., (2018),, which highlighted the potent antimicrobial and antioxidant properties of phenolic compounds in potato peels, contributing to shelf life extension. In addition, the incorporation of turmeric—rich in curcumin—further enhances the antimicrobial efficacy of the edible films. Comparable results were reported by Xie et al., (2020), who developed a biodegradable film combining potato peels, curcumin, and bacterial cellulose, which effectively prevented lipid oxidation in sausages. In the present study, all treatments showed an increase in bacterial counts up to 60 days of storage, followed by a decline. This decline was more pronounced in samples with higher concentrations of potato peel powder in the coating film. These results are consistent with those of El-Sisi et al., (2015). Regarding yeast and mold counts, no fungal growth was detected at the beginning of the ripening period. Fungal growth began around day 30 in the uncoated cheese and around day 90 in the coated samples, reaching its highest level in the uncoated cheese by the end of ripening. This trend can be attributed to reduced oxygen

oxygen levels in the coated cheese, which create unfavorable conditions for fungal proliferation (EL-Sisi et al., 2015). Among the coated treatments, the 3% PPP coating (T3) exhibited the lowest yeast and mold counts by day 90. This is likely due to the antifungal activity of phenolic compounds in potato peels and curcumin in turmeric. Kapoor (1997) also confirmed that turmeric extract, especially when combined with ginger, exhibits strong antifungal activity against species such as *Penicillium digitatum* and *Aspergillus niger.*

Table 4. Microbiological quality (log cfu/g) of Ras cheese coated with potato peel based edible film when fresh and during ripening period at 15±2ºC for 90 days.

Parameter	Storage period (days)	Treatments*			
		C	T_1	T_2	T_3
Total bacterial count (TBC)	Zero	6.34^{Abc}	6.21^{Bd}	6.20^{Bd}	6.21^{Bd}
	30	6.48^{Aa}	6.37^{ABb}	6.34^{Bbc}	6.30^{Cc}
	60	5.66^{Ae}	5.48^{Bf}	5.00^{Cg}	4.67^{Dh}
	90	4.20^{Ai}	4.12^{ABj}	3.76^{Bk}	3.20^{Cl}
Mould&Yeast (M&Y)	Zero	ND	ND	ND	ND
	30	1.20^{Ac}	ND	ND	ND
	60	1.82^{Ab}	ND	ND	ND
	90	2.95^{Aa}	1.00^{Bd}	0.96^{Ce}	0.90^{Df}

ND: Not detected
*** C, T_1, T_2, T_3: Ras cheese samples coated with 0, 1, 2 and 3% potato peel powder film respectively.**
A,B,C : Means with the same letter among treatments are not significantly different (P≤0.05)
a,b,c : Means with the same letter during storage period are not significantly different (P≤0.05)

Textural analysis of Ras cheese

Based on the data presented in Table 5, it is evident that cheese texture an important determinant of quality and consumer acceptability is influenced by several parameters, including cohesiveness, adhesiveness, gumminess, chewiness, springiness, and hardness. The results clearly demonstrate that incorporating potato peel powder (PPP) into the edible coating film reduced moisture loss, which consequently led to a decrease in cheese hardness compared to the uncoated control. This observation supports the well-established inverse relationship between cheese hardness and moisture content, as previously reported by Ibrahim et al., (2023). Nevertheless, hardness increased gradually in all treatments, including the control, over the 90-day storage period at 15±2 °C, likely due to progressive moisture loss during ripening. An inverse relationship was also noted between adhesiveness and the other texture parameters cohesiveness, hardness, gumminess, chewiness, and springiness. All of these parameters (except adhesiveness) increased with higher PPP concentrations relative to the control. Among the coated treatments, T1 and T2 exhibited the most notable improvements in textural properties, with T2 showing the highest values across most parameters. With regard to cohesiveness, gumminess, chewiness, and springiness, all cheese samples including the control showed their highest values by day 90, indicating that textural development continued throughout the ripening period.

Sensory evaluation of Ras cheese

The sensory evaluation results of Ras cheese samples coated with varying concentrations of potato peel powder (PPP) are presented in Table 6. All cheese treatments showed an overall improvement in flavor, body and texture, and appearance throughout the ripening period. Notably, cheese coated with 2% PPP (T2) achieved the highest total sensory score (94.88) at day 90, which was significantly higher (P ≤ 0.05) than that of the control (93.61) and other treatments. In terms of flavor, T2 consistently outperformed the control and T1 across all storage intervals, with statistically significant differences observed at days 60 and 90. Similarly, for body and texture, T2 showed superior performance, with scores increasing from 34.50 on day 0 to 38.00 on day 90 significantly higher ($P \leq 0.05$) than those of the control and T3. The appearance of the coated cheeses was also enhanced, particularly in T2, due to the light yellow tint and mild aroma imparted by turmeric. At day 90, T2 recorded the highest appearance score (9.00), contributing to its overall sensory acceptability. These results confirm that coating Ras cheese with 2% PPP and turmeric not only improves microbial stability but also significantly enhances its sensory attributes. This is consistent with the findings of El-Sisi et al.,(2015) and Gammariello et al., (2010),, who reported that chitosan-based coatings effectively improve the organoleptic properties of cheese. Furthermore, these findings support the observations of Appendini and Hotchkiss (2002), who noted that coatings enriched with food additives such as organic acids, enzymes, bacteriocins, fungicides, natural extracts, spices, and vitamins can extend shelf life by reducing pathogen risk while simultaneously enhancing the sensory quality of the coated product.

Table 5. Textural properties of Ras cheese coated with potato peel based edible film when fresh and during ripening period at 15±2ºC for 90 days.

Parameter	Storage period (days)	Treatments*			
		C	T_1	T_2	T_3
Hardness (N)	Zero	98.8	88.7	88.2	84.7
	30	138.6	120.4	115.7	115.4
	60	142.5	126.4	103.3	104.6
	90	193.3	181.1	177.5	174.9
Adhesiveness (mj)	Zero	0.409	0.447	0.424	0.414
	30	0.204	0.213	0.228	0.220
	60	0.148	0.160	0.166	0.159
	90	0.084	0.098	0.113	0.096
Cohesiveness (ratio)	Zero	0.27	0.30	0.30	0.28
	30	0.34	0.48	0.47	0.38
	60	0.45	0.50	0.50	0.49
	90	0.58	0.62	0.64	0.61
Springiness (mm)	Zero	3.94	4.40	4.50	4.03
	30	5.97	5.98	5.99	5.96
	60	5.98	6.00	6.11	6.00
	90	6.00	6.28	6.31	6.09
Gumminess (N)	Zero	26.8	33.7	38.8	31.4
	30	41.5	44.9	46.9	43.0
	60	52.3	56.8	59.8	53.4
	90	61.8	65.9	70.8	63.4
Chewiness (mj)	Zero	157.25	167.36	190.36	157.30
	30	201.50	210.67	269.04	206.21
	60	313.11	356.97	380.05	338.46
	90	422.24	493.38	506.38	477.83

*C, T_1, T_2, T_3: Ras cheese samples coated with 0, 1, 2 and 3% potato peel powder film respectively

Table 6. Sensory properties of Ras cheese coated with potato peel based edible film when fresh and during ripening period at 15±2ºC for 90 days

Parameter	Storage period (days)	Treatments*			
		C	T_1	T_2	T_3
Flavor (50)	zero	42.00	42.50	42.78	42.75
	30	44.84	45.13	45.36	45.31
	60	46.25	46.25	46.75	46.53
	90	47.50	47.65	47.88	47.69
Body and texture (40)	zero	34.15	34.25	34.50	34.25
	30	35.33	35.55	35.79	35.72
	60	34.75	35.75	36.50	36.50
	90	37.50	37.54	38.00	37.63
Appearance (10)	zero	8.22	8.25	8.33	8.00
	30	8.39	8.43	8.50	8.16
	60	8.47	8.50	8.75	8.23
	90	8.63	8.87	9.00	8.31
Total (100)	zero	84.37^{Ck}	85.00^{ABj}	$85,61^{Ai}$	85.00^{Bj}
	30	88.56^{Ch}	89.11^{Bg}	89.65^{Af}	89.19^{Bg}
	60	89.47^{Dfg}	90.50^{Ce}	92.00^{Ac}	91.26^{Bd}
	90	93.61^{Cb}	94.06^{Bb}	94.88^{Aa}	93.63^{Cb}

C, T_1, T_2, T_3: Ras cheese samples coated with 0, 1, 2 and 3% potato peel powder film respectively.
A,B,C :Means with the same letter among treatments are not significantly different ($P \leq 0.05$)
a,b,c : Means with the same letter during storage period are not significantly different ($P \leq 0.05$).

4. Conclusion

This study demonstrated that edible films incorporating potato peel powder (PPP) and turmeric effectively improved the quality, safety, and shelf life of Ras cheese during ripening. Cheese samples coated with these films particularly those containing 2% PPP exhibited significantly lower microbial counts, reduced weight loss, and enhanced textural properties compared to the uncoated control. The addition of turmeric likely contributed to the antimicrobial efficacy of the coating due to its curcumin content. These results highlight the potential of PPP-based edible films as a sustainable and natural alternative to synthetic coatings for cheese preservation. Further research is recommended to assess consumer acceptability and the feasibility of scaling up this approach for industrial applications.

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