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Development of Composite Film and Coating Incorporated With Cinnamon Essential Oil and Its Effect on the Quality of Chicken Patties

Aditi Sawant[1], V. H. Shukla[1*], R. J. Zende[2], V. M. Vaidya[2]

[1]Department of Livestock Products Technology, Mumbai Veterinary College, Parel, Mumbai-400012, INDIA
[2]Department of Veterinary Public Health, Mumbai Veterinary College, Parel, Mumbai-400012, INDIA

*Corresponding Author: drvivekivri@gmail.com

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Abstract

The work was done to develop and evaluate the edible film and coating of starch and chitosan incorporated with cinnamon essential oil on the quality of chicken patties for 30 days at refrigerated storage. The edible film and coating were prepared using 1% chitosan, 2% starch incorporated with 0.5% cinnamon essential oil, and wrapped around chicken patties. The results indicated a significant improvement in physico-chemical and microbiological parameters of chicken patties in treatments compared to controls. The texture and color parameters were maintained in treatments compared to the control throughout the storage period, while no sensory discrimination was observed in treatments upon application of edible film and coating. The control had a shelf life of 10 days, while treatments were shelf-stable even up to the 15th day of refrigeration storage. Thus, a shelf-life extension of more than five days was achieved in chicken patties coated with edible film and coating compared to control during refrigeration storage (4±1°C).

Keywords: Edible Film, Coating, Cinnamon Essential Oil, Chitosan, Natural Preservation.

Introduction

Livestock production is a significant source of income for the country's rural poor where small farm households receive 16% of their income from livestock, compared to 14% on average from all rural households (BAHS, 2024). The biggest challenge to the industry is limited shelf life and early spoilage which could be effectively tackled by packaging which is an integral and critical requirement for extending shelf life, increasing food safety and thereby promoting food security. Among the various types of packaging, active packaging has emerged as a tool to fulfil consumer demand for natural, recyclable, and biodegradable packaging materials. (Majid *et al.*, 2018). Edible films are excellent barrier to external changes as they reduce moisture escape from food products, minimizing microbiological growth, changes in texture, and unfavourable chemical and enzymatic reactions (Zhang *et al.*, 2018).

Natural polymers such as chitosan, starch, carrageenan, carboxymethyl cellulose, gelatin have been widely used in preparation of edible coating and films and they offer various advantages such as increased shelf-life, antimicrobial activity etc. Essential oils (EOs), which are natural extracts obtained from various spices and herbs have been used to control the safety and quality of meat products (Macwan *et al*., 2016).

Since the application of edible film and coating for preservation of meat and meat products is a new area of research with the possibility of exploration, the present research work has been planned to develop edible film and coating incorporated with cinnamon essential oil and to evaluate its effects on the quality of chicken patties.

Materials and Methods

Preparation of Edible Coating and Film

For the preparation of plain edible coating, 2.0 g of chitosan was dissolved in 100 mL distilled water and 1.0 mL acetic acid was added to it. After that, 1.0 mL of cinnamon essential oil was added and stirring was done at 1000 rpm for 60 minutes. 4.0 g of starch was dissolved in 100 mL of distilled water by heating at 90 ˚C for 30 minutes and 40.0 mL glycerol / 100 g of starch was added to it, while stirring at 90 ˚C for 30 minutes at 500rpm. Both the solutions were mixed and stirred at 1000 rpm for 20 minutes to remove the air bubbles to form edible coating (T_1). After that 75 mL of solution was poured into a petri dish of 14.5 cm diameter and drying was done at 45 ˚C for 24 hours to obtain the plain edible film (T_2). Thus, the plain edible coating (T_1) and plain edible film (T_2) of 1% chitosan, 2% starch incorporated with 0.5% cinnamon essential oil were prepared.

Experimental Design

For determination of quality and shelf-life of chicken patties coated with edible coating and film, following treatments were made; Control: Chicken patties without any edible coating of film; T_1: Chicken patties covered with coating of chitosan and starch incorporated with cinnamon essential oil; T_2: Chicken patties coated with edible film of chitosan and starch incorporated with cinnamon essential oil. All the treatments were packed in LDPE film and stored at refrigeration while determination of quality and shelf-life was done at interval of 5 days till spoilage using different quality parameters.

Physico-Chemical Parameters

The pH was recorded by combined glass electrodes of a digital pH meter (Model T-25, Janke and Kenkel, 1KA Labor Technik, Germany) in homogenate as per Trout *et al*. (1992). Tyrosine value was estimated as per the method of Strange *et al*. (1977) and expressed in mg/100 g. Thiobarbituric acid reacting substances (TBARS) was estimated by the procedure of Witte *et al*. (1970) and expressed as mg malonaldehyde/kg of sample. Antioxidant activity was determined by DPPH free radical scavenging activity as per the method of Tepe *et al*. (2005).

Microbiological Quality

The samples were analyzed for total plate count (TPC), yeast and mould count, psychrophilic count and coliform count as per APHA (2001).

Sensory Evaluation

Sensory evaluation of chicken patties was performed by the method described by Keeton (1983) using an 8-point descriptive scale, where 8 were given for the extremely liked product and 1 for extremely disliked.

Hunter Color Analysis

Color measurements (L*, a*, b*, Hue and Chroma values) were carried out using an Ultra Scan Vis spectrophotometer (Hunter Lab, Reston, VA, USA) as per the procedure described by Ledesma *et al*. (2016).

Statistical Analysis

The experiments were repeated three times in duplicate and the data generated for different quality characteristics were compiled and analyzed using SPSS (version 26 for Windows; SPSS, Chicago, III., U.S.A.) with three replicates (N=6). The data were subjected to analysis of variance and the level of significance was reported at 5% level of significance (P<0.05).

Result and Discussion

Physicochemical Parameters

The pH values rose over the course of the storage period (Table 1). T_1 and T_2 have the lower pH than others, which may be due to the inhibition of microbial activity preventing the protein breakdown due to presence of cinnamon essential. The results were similar to the findings of Brilliana *et al*., (2017), who stated that compared to the control sample, the pH levels of ground lamb incorporated with 0.025% and 0.05% cinnamon bark essential oil were lower than control.

The lipid oxidation which is used to measure TBARS value, showed an increase over the storage period (Table1). During the storage period, TBARS value in T_2 was considerably (P<0.05) lower than the control and T_1. The results corroborated with the findings of Zhao *et al*., (2022), edible film of chitosan and cinnamon-perilla essential oil reduced the fish lipid oxidation in treatments than control during refrigeration storage. Azadi *et al*., (2023) found that chitosan, tragacanth gum, and polyvinyl alcohol composite coatings combined with cinnamon essential oil significantly reduced the TBARS value in chicken fillets during the refrigeration storage than control.

The DPPH activity decreased significantly (P<0.05) with time in all treatments (Table1), which could be due to oxidative chain reactions. However, it was significantly maintained in T_1 and T_2 than control which could be due to the enhanced anti-oxidative activity due to cinnamon essential oil. Similar results were observed by Youssef *et al*., (2023) who also found that in edible film made from chitosan and cinnamon essential oil nano-emulsion had increased free radical scavenging activity.

The tyrosine value increased throughout the storage period (Table1) among all the treatments. The control had the highest value, followed by T_1 and T_2. The significant (P < 0.05) decrease in T_2 compared to all treatments may be due to antimicrobial property of chitosan and cinnamon essential oil. Sheerzad *et al*., (2024) reported a similar outcome where chicken meat was coated with chitosan and cinnamon essential oil had lower tyrosine value than control. Sonar *et al*., (2023) stated that the higher antibacterial activity of edible coatings containing chitosan and clove essential oil might have restricted the protein degradation in treatments, resulting in a lower tyrosine value in treatments compared to control.

Microbiological Quality

With respect to the total plate count (TPC), as the storage period progressed, all the treatments showed an in microbial load (Figure 1). The microbial load crossed the permissible limit of $4\log_{10}$ CFU/g on 10th day of storage in control. However, T_1 and T_2 were below the permissible limit even after 15th day of storage period. Among all the treatment T_2 showed the lowest microbial load which could be due to the antimicrobial effect of chitosan and cinnamon essential oil. The results corroborated with the findings of Mukhtar *et al.* (2018) who reported that poultry meat dipped in 1% solution of chitosan, 2% solution of starch and 1.5% clove essential oil, had a significant decrease in microbiological count than control.

Table 1: Effect of edible coating and film of starch and chitosan incorporated with cinnamon essential oil on physico-chemical parameters of chicken patties during refrigeration storage (4±1ºC) (Mean±S.E.)*

Refrigerated storage period (days)					
Treatments	Day 1	Day 5	Day 10	Day 15	Day 20
pH					
Control	6.9 ± 0.01 ^{a1}	7.19± 0.02^{a2}	7.23±0.05 ^{a3}	7.5 ± 0.08^{a4}	NE
T_1	6.85 ± 0.04 ^{a1}	7.10 ±0.01 ^{b2}	7.15± 0.01 ^{b3}	7.27 ± 0.01 ^{b4}	7.36 ± 0.05 ^{a5}
T_2	6.76 ± 0.02^{b1}	7.06 ± 0.02 ^{c2}	7.02 ± 0.01^{c3}	7.18 ± 0.05^{c4}	7.30± 0.02^{b5}
TBARS (mg malonaldehyde/kg of meat)					
Control	0.20±0.05^{a1}	0.44 ±0.2 ^{a2}	0.51±0.01^{a3}	0.94 ± 0.01^{a4}	NE
T_1	0.16±0.04^{b1}	0.32 ±0.3 ^{b2}	0.48±0.08^{a3}	0.86 0.01 ^{b4}	0.96±0.01^{a5}
T_2	0.14±0.03^{b1}	0.25 ±0.4 ^{c2}	0.34±0.14^{c3}	0.76±0.02^{c4}	0.85±0.01^{b5}
Tyrosine (mg/100g)					
Control	25.15±0.02^{a1}	26.37±0.01^{a2}	28.13±0.02^{a3}	32.52±0.01^{a4}	NE
T_1	24.14±0.08^{b1}	25.33±0.07^{b2}	27.46±0.08^{b3}	30.39 ±0.0^{b4}	34.14 ±0.0^{a5}
T_2	23.27±0.021^{c1}	24.30±0.05^{c2}	26.92±0.01^{c3}	29.12±0.02^{c4}	33.31±0.02^{b5}
DPPH (%)					
Control	14.83±0.4 ^{d1}	13.16±0.16^{d2}	11.83±0.44^{d3}	10.03±0.30^{d4}	NE
T_1	16.83±0.44^{c1}	15.86±0.40^{c2}	14.36±0.16^{c3}	10.34±0.01^{c4}	9.10 ± 0.01^{b4}
T_2	18.16±0.44^{b1}	17.31±0.15^{b2}	16.34±0.17^{b3}	11.26±0.24^{b4}	10.31±0.07^{c5}

*N=6; NE: Not estimated; *Mean ±S.E. bearing different superscripts row-wise (small alphabet) and column-wise (numerals) indicate a significant difference (P< 0.05)*

There was no yeast or mould growth during initial five days in any of the treatments, but their number increase after that with the progression of storage period (Figure 1). T_2 had lowest yeast and mould count among all the treatments which could be due to antimicrobial property of chitosan and cinnamon essential oil. During the storage period, no coliforms were found which may be due to strict hygienic measures used during preparation and preservation of the chicken patties and due to the antimicrobial activity of the edible film and coating. Similarly, Shraouba *et al.* (2022) found that chitosan film containing thyme and clove essential oil significantly inhibited the coliform in meat products. There were no psychrophiles in either the control sample or the treatments throughout the storage period. The inclusion of chitosan and cinnamon essential oil, having antibacterial properties, may be the reason for the absence of psychrophiles during refrigeration storage.

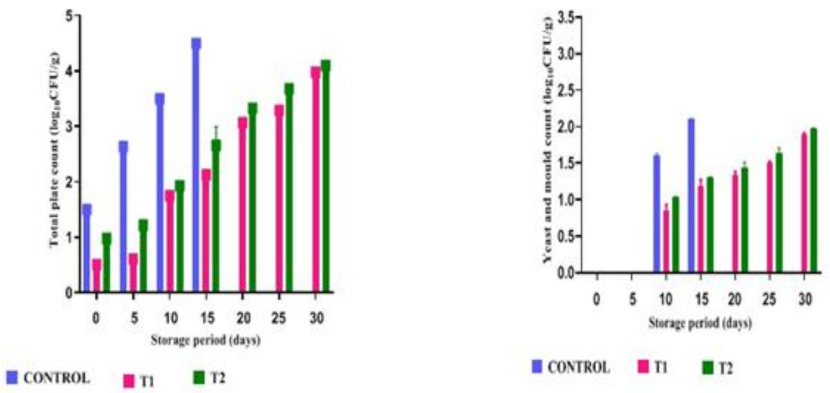

Figure 1: Effect of edible coating and film of starch and chitosan incorporated with cinnamon essential oil on microbiological qualities of chicken patties during refrigeration storage (4±1°C)

Hunter Color Analysis

The lightness(L*) values decreased significantly (P<0.05) in all the treatments over a period of time (Table 2). The redness (a*) value decreased with the progression of storage period which might have been caused by the production of free radicals from lipid oxidation and met myoglobin formation. Kulawik *et al.* (2024) reported that protein breakdown, water loss from the meat, oxymyoglobin oxidation to metmyoglobin during storage, are the causes of decreased redness value in pork loin during storage period and similar reasons might have caused the decreased redness in the present study. The yellowness (b*) value decreased in all the treatments with the progression of storage period in all the treatments (Table 2). The results could be attributed to the conversion of myoglobin in pork to metmyoglobin during storage, gradually changed the color, which might be the reason for decreased yellowness in the treatments in the present study.

Chroma values decreased significantly (P<0.05) with the progression of storage period in all the treatments (Table 2). However, chroma value was significantly maintained in T_2 than other treatments during storage period. The results corroborated with the findings of Peighambardoust *et al.* (2022), who reported that fresh meat coated with chitosan and yarrow essential oil had the higher chroma value than control during storage period. With respect to the hue value, it did not change significantly across any treatments over the storage period.

Table 2: Effect of edible coating and film of starch and chitosan incorporated with cinnamon essential oil on hunter color analysis of chicken patties during refrigeration storage (4±1ºC) (Mean±S.E.)*

	Refrigerated storage period (days)				
Treatments	**Day 1**	**Day 5**	**Day 10**	**Day 15**	**Day 20**
Lightness (L*)					
Control	57.60 ± 0.01^{a1}	56.71 ± 0.01^{a2}	54.80 ± 0.08^{a3}	52.53 ± 0.02^{b4}	NE
T_1	55.61 ± 0.01^{b1}	55.32 ± 0.01^{b2}	53.12 ± 0.01^{b3}	51.04 ± 0.2^{d4}	50.45 ± 0.02^{c5}
T_2	54.35 ± 0.18^{c1}	54.33 ± 0.11^{c2}	53.02 ± 0.01^{c3}	52.32 ± 0.01^{c4}	50.66 ± 0.01^{b5}
Redness (a*)					
Control	6.34 ± 0.05^{e1}	6.12 ± 0.01^{e2}	5.92 ± 0.01^{e3}	5.60 ± 0.02^{c4}	NE
T_1	6.65 ± 0.02^{d1}	6.21 ± 0.01^{d2}	6.06 ± 0.01^{d3}	5.89 ± 0.01^{b4}	5.6 ± 0.02^{d5}
T_2	6.82 ± 0.014^{c1}	6.41 ± 0.012^{c2}	6.11 ± 0.02^{c3}	6.10 ± 0.01^{a3}	6.08 ± 0.03^{c4}
Yellowness (b*)					
Control	27.56 ± 0.03^{e1}	27.48 ± 0.01^{e2}	26.34 ± 0.07^{e2}	26.10 ± 0.01^{e3}	NE
T_1	29.49 ± 0.032^{d1}	28.21 ± 0.03^{d2}	27.35 ± 0.012^{d3}	26.53 ± 0.01^{d4}	26.11 ± 0.03^{d5}
T_2	30.39 ± 0.011^{c1}	29.14 ± 0.05^{c2}	28.25 ± 0.012^{c3}	27.34 ± 0.08^{c4}	27.02 ± 0.01^{c5}
Chroma					
Control	28.27 ± 0.06^{e1}	28.18 ± 0.03^{e2}	27.18 ± 0.04^{d3}	26.65 ± 0.07^{e4}	NE
T_1	30.33 ± 0.08^{d1}	28.76 ± 0.80^{d2}	27.40 ± 0.18^{d3}	27.48 ± 0.08^{d4}	26.49 ± 0.14^{d5}
T_2	31.14 ± 0.02^{c1}	29.72 ± 0.04^{c2}	28.72 ± 0.04^{c3}	27.87 ± 0.01^{c4}	27.51 ± 0.032^{c5}
Hue					
Control	1.35 ± 0.04^{b2}	1.36 ± 0.02^{ab1}	1.35 ± 0.05^{a2}	1.36 ± 0.03^{ab1}	NE
T_1	1.34 ± 0.03^{b2}	1.35 ± 0.05^{b1}	1.34 ± 0.04^{a2}	1.32 ± 0.02^{bc3}	1.35 ± 0.02^{a1}
T_2	1.36 ± 0.05^{a2}	1.36 ± 0.04^{a2}	1.33 ± 0.06^{a4}	1.38 ± 0.03^{a1}	1.34 ± 0.05^{b3}

*N=6; NE: Not estimated; *Mean ±S.E. bearing different superscripts row-wise (small alphabet) and column-wise (numerals) indicate a significant difference (P< 0.05).*

Sensory Evaluation

The sensory scores of chicken patties coated with edible film and coating of starch and chitosan incorporated with clove essential oil is presented in Table 3. The appearance and color scores decreased significantly (P<0.05) as the storage time progressed in all the treatments. However, the edible film and coating significantly maintained the appearance and color scores in treatments than control. The flavor of both control and treatments reported significant (P<0.05) decrease throughout the storage but was maintained in treatments than control during storage period. The texture score also followed a decreasing trend in all the treatments during storage period. Similar results were also observed for meat flavor intensity scores where a decreasing trend was observed with the progression of storage period. The results were in line with the findings of Sonar *et al.* (2023) who found that chicken patties coated with edible coating of chitosan incorporated with clove essential oil has significantly superior sensory qualities than control during storage period.

As the storage period progressed, there was significant ($P<0.05$) decrease in overall acceptability scores in all the treatments. When compared to other treatments, the overall acceptability score was considerably higher in T_1 and T_2 as the storage period progressed. Azadi *et al.* (2023) found that when the chicken breast fillets were treated with coating of chitosan and cinnamon essential oil, the sensory scores were significantly higher in treatments than control during 21 days of refrigeration storage.

Table 3: Effect of edible film and coating of starch and chitosan incorporated with cinnamon essential oil on sensory qualities of chicken patties during refrigeration storage (4±1 ºC)

	Refrigerated storage period (days)				
Treatments	**Day 1**	**Day 5**	**Day 10**	**Day 15**	**Day 20**
Appearance and color					
Control	$7.5±0.03^{b1}$	$7.4±0.03^{a2}$	$6.8±0.03^{c3}$	$5.76±0.03^{d4}$	NE
T_1	$7.51±0.02^{b1}$	$7.42±0.02^{a2}$	$7.07±0.03^{b3}$	$6.24±0.03^{bc4}$	$5.45±0.06^{c5}$
T_2	$7.53±0.03^{ab1}$	$7.3 ± 0.05^{c2}$	$7.00± 0.03^{b3}$	$6.36±0.03^{a4}$	$5.52± 0.01^{b5}$
Flavor					
Control	$7.51±0.08^{a1}$	$7.49±0.03^{a2}$	$6.97±0.06^{d3}$	$4.76±0.03^{e4}$	NE
T_1	$7.44±0.05^{b1}$	$7.42±0.03^{a1}$	$7.32±0.05^{a2}$	$5.24±0.08^{c3}$	$4.1 ±0.05^{d4}$
T_2	$7.12±0.08^{c3}$	$7.09±0.01^{b4}$	$7.06±0.08^{bc3}$	$5.36± 0.05^{a2}$	$4.15±0.03^{c1}$
Texture					
Control	$7.53±0.01^{c1}$	$7.51±0.05^{c2}$	$6.9± 0.05^{c3}$	$6.67±0.03^{b4}$	NE
T_1	$7.56±0.03^{b1}$	$7.52±0.08^{c2}$	$7.31±0.05^{a3}$	$6.45±0.05^{c4}$	$6.13±0.033^{c5}$
T_2	$7.58±0.03^{b1}$	$7.54±0.03^{b2}$	$7.21±0.05^{a3}$	$6.26±0.05^{d4}$	$6.15±0.05^{c5}$
Meat flavor intensity					
Control	$7.64±0.01^{b1}$	$7.4 ±0.05^{b2}$	$6.68±0.04^{c3}$	$6.66±0.05^{d4}$	NE
T_1	$7.6±0.06^{b1}$	$7.42±0.01^{a2}$	$7.23±0.05^{b3}$	$7.21±0.08^{b4}$	$6.54±0.08^{b5}$
T_2	$7.5±0.01^{b1}$	$7.35±0.05^{c2}$	$7.30±0.01^{ab3}$	$7.15± 0.05^{c4}$	$7.11±0.08^{a5}$
T_3	$7.83±0.10^{a1}$	$7.40±0.03^{ab2}$	$7.39±0.04^{a3}$	$7.15± 0.01^{a4}$	$7.07± 0.37^{a5}$
T_4	$7.41±0.05^{c1}$	$7.38±0.05^{ab2}$	$6.32± 0.01^{d3}$	$6.22± 0.01^{e4}$	$6.14± 0.05^{c5}$
Overall acceptability					
Control	$7.61±0.05^{a1}$	$7.46±0.02^{a2}$	$6.87±0.03^{c3}$	$6.67±0.05^{b4}$	NE
T_1	$7.51±0.05^{c1}$	$7.43±0.012^{a2}$	$7.26±0.018^{b3}$	$7.21 ± 0.08^{a4}$	$6.55 ±0.02^{b5}$
T_2	$7.50±0.03^{c1}$	$7.44±0.01^{a2}$	$7.22±0.01^{b3}$	$7.15±0.05^{a4}$	$7.07±0.03^{a5}$

*N=6; NE: Not estimated; *Mean ±S.E. bearing different superscripts row-wise (small alphabet) and column-wise (numerals) indicate a significant difference (P< 0.05)*

Conclusion

Edible coating and film of 1% chitosan, 2% starch incorporated with 0.5% cinnamon essential oil could be successfully prepared and applied over chicken patties for improvement of quality and shelf-life. The application of edible film and coating improved the quality parameters in chicken patties than control. Throughout the storage period pH, TBARS, Tyrosine, microbiological quality, sensory qualities, hunter color and texture parameters were significantly improved in T_1 and T_2 than control. The shelf life of control was 10 days while T_1 and T_2 were shelf-stable even after 15 days at refrigeration storage. Accordingly, it can be concluded that the use of edible coating and film of starch and chitosan incorporated with clove essential oil could effectively enhance the quality and prolong the shelf-life of chicken patties than control during refrigeration storage.

Contribution by Authors

All the authors contributed equally to writing the manuscript. The final manuscript was read by all authors and consented to publication.

Conflict of Interests

There is no conflict of interest.

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