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Research Article

QUALITY ATTRIBUTES AND SHELF-LIFE EVALUATION OF GOAT MEAT WITH INDIAN CURD EXTRACT, LACTIC ACID, AND NISIN UNDER REFRIGERATED CONDITIONS

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ABSTRACT: The quality and shelf life of raw goat meat (chevon) decline due to microbial and oxidative processes during storage. This study aimed to evaluate the storage stability of raw chevon treated with crude extract (CE) from Indian curd, lactic acid, and nisin at a refrigerated temperature of 4±1°C. Various batches of raw goat meat were analyzed: an untreated control (C), meat treated with a 2% (w/v) concentration of CE (T1), 0.5% lactic acid (T2), and 10 ppm nisin (T3). These samples were assessed for physico-chemical, microbial, and sensory characteristics under aerobic packaging conditions every other day for seven days. Results indicated that the pH, free fatty acids, thiobarbituric acid reactive substances, and peroxide values were significantly higher ($p<0.05$) in the control group compared to the treated samples, with T1 exhibiting notably lower values. Throughout the storage period, the extract release volume and water activity (aw) decreased for all samples, but T1 maintained significantly higher values ($p<0.05$). Among the samples, T1 had the lowest bacterial count. On the first day, there were no significant differences ($p>0.05$) in color and odor scores between the control and treated samples, except T2, which had a lower color rating. Conversely, T1 received significantly higher sensory scores towards the end of the storage period ($p<0.05$). Overall, the findings suggest that CE from Indian curd is the most effective preservative in this study, extending the shelf-life of T1 to an acceptable limit of seven days, compared to five days for the control. This comparative analysis concludes that CE from Indian curd can be effectively utilized as a biopreservative to enhance the shelf life of raw goat meat.

Keywords: Indian curd extract, Bio-preservative, Nisin, Lactic acid, Meat quality, Storage stability.

INTRODUCTION

Meat, particularly goat meat (chevon), is quite popular and constitutes an important part of the diet of non-vegetarians because of its unique taste and high nutritive value [1, 2]. However, being perishable in nature, raw goat meat (chevon) has a limited shelf life. The shelf life decreases due to microbial and oxidative changes during storage affecting the nutritional, physiological, and sensory qualities of meat [3]. The microbial proliferation in raw meat may lead to a potential outbreak of meat-borne illness and, hence needs to be controlled to ensure food safety [4]. To overcome this, physical, chemical, and biological methods are employed to protect meat from spoilage microorganisms and pathogenic bacteria in order to improve shelf-life. However, many of these chemical preservatives have adverse health effects [5]. Considering the need for the safety and quality of raw meat and the demand for chemical-free additives, natural preservatives having antimicrobial and antioxidant activities are being used at the present time as alternatives by meat manufacturers and

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researchers, replacing chemical preservatives for ensuring food safety and quality [6, 7, 8]. In this regard, natural preservatives from microorganisms that produce bacteriocins have an antagonistic effect on spoilage and pathogenic microorganisms [9]. Among various bacteriocins, nisin is a representative class I bacteriocin obtained from *Lactococcus lactis*. Being a generally regarded as safe (GRAS) product, nisin is approved for use as a biopreservative in meat, dairy products, processed cheese, vegetables, etc. in many countries [10]. This is due to its long-lasting bacteriostatic effects against a wide range of pathogenic microorganisms, and food safety characteristics [11]. Likewise, lactic acid, one of the GRAS organic acids (21 CFR, 172.515), is used as a preservative in different food matrix, including meat to improve quality and safety. This acid is used as a decontaminating strategy and is known for its effectiveness in delaying the proliferation of microbes [12, 13], apart from improving sensory attributes such as the odor and taste of meat [14].

In the recent past, various bio-physiologically active substances have been isolated from milk [15] and milk products such as cheese [16], yogurt [17], curd [18], etc. Out of these, curd, a fermented milk product is popular in India and consumed by many people, either as a beverage or part of daily diet. The crude extract (CE) obtained from Indian curd exhibits antioxidant and antimicrobial effects and, hence can be used as a food biopreservative.

In our previous study, characterization of the CE from Indian curd was done for its application as a potential biopreservative in foods. The CE exhibited pronounced antioxidant properties as evident from DPPH free radical scavenging and ferric reducing antioxidant power assay, antimicrobial activity against foodborne pathogenic bacteria like *Salmonella* Typhimurium, *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Bacillus cereus*, very good temperature, pH, freeze-thaw and storage stability. Trypsin digestion confirmed the proteinaceous nature of the CE and the analysis of SDS-PAGE band patterns revealed the presence of peptides of 10-30 kDa, 51-71 kDa, and 137-180 kDa molecular weights in CE [18].

In earlier studies, paneers treated with CE from Indian curd exhibited superior physical, sensory, and microbial qualities compared to those treated with nisin and lactic acid during storage at refrigerated temperatures for up to 12 days [19]. This study aims to assess the physico-chemical, microbiological, and sensory characteristics of chevon treated with CE from Indian curd, 0.5% lactic acid, and 10 ppm nisin during refrigerated storage at 4±1°C, evaluated every other day for a week.

MATERIALS AND METHODS

Procurement of goat meat

Fresh goat meat (chevon) was sourced from the experimental abattoir of the Division of Livestock Products Technology (LPT), ICAR-Indian Veterinary Research Institute (IVRI) located at Izatnagar, Bareilly, UP, India. The primary muscles from the hind limbs of adult male goats, aged 9 to 11 months, including the biceps femoris, semimembranosus, and longissimus thoracis et lumborum, were carefully deboned. Tendons, excess fat, and connective tissues were also removed. The meat was then packed in low-density polyethylene (LDPE) bags (200 gauges) and stored at 4±1°C for approximately 12 hours for conditioning, before being frozen at -20±1°C until needed. Prior to the experiments, the samples were thawed overnight in a refrigerator set at 4±1°C.

Proximate composition

Prior to the storage study, the proximate composition *viz.*, moisture%, protein%, fat%, and ash% of the goat meat were determined as per the standard methods of AOAC [20].

Preparation of curd

Curd was prepared from the pasteurized milk procured from the Dairy Section, ICAR-IVRI, Izatnagar by inoculating the milk with 2% starter culture of the selected household curd (result not presented) followed by fermentation at room temperature for 18-20 hours [21].

Preparation of crude extract (CE) of curd

The crude extract (CE) was prepared using the techniques outlined by Samlesh and Shilpa [22] with slight modifications [18]. In each preparation, 40 mL of curd was placed in a sterile glass beaker and homogenized for 3 to 5 minutes. The mixture was then centrifuged at 8,000 rpm for 20 minutes using a Hermle Z 32 HK centrifuge. The resulting protein-rich supernatant, approximately 20 mL, was collected and filtered through Whatman no. 1 filter paper. The supernatant was concentrated using a lyophilizer (Modulyo, Edwards) in separate batches. Each batch of the lyophilized extract, around 1.5 g, was then reconstituted with sterile distilled water at pH 7.0 to

achieve a final volume of 2 mL, creating a 10-fold concentrated solution of the curd supernatant.

Determination concentration of CE for incorporation into chevon

Various concentrations of the crude extract (CE), specifically 2, 3, 4, 5, and 10-fold, were prepared by diluting the original 10-fold concentrated stock with sterile distilled water at pH 7.0. The effective concentration of the CE to be incorporated in chevon samples was assessed against *B. cereus* and *S.* Typhimurium using the agar well diffusion method.

Preparation of chevon samples for storage life study

The raw deboned chevon was cut into small cubes/ dice. Based on the antimicrobial activity, the 5-fold concentrated crude extract was used @ 2% (w/v) of the raw chevon which was designated as T1. Similarly, the chevon samples were treated with 0.5% (w/v) lactic acid and with 10 ppm nisin and designated as T2 and T3, respectively. The untreated chevon sample was marked as control (C). As already mentioned in the introduction section, curd contains various bio-preservatives like lactic acid, bacteriocins *viz.*, nisin, pediocin, etc., bioactive peptides, H_2O_2, etc. Hence, in the present study, the activity CE in preserving raw chevon was compared with widely used food preservatives of dairy origin like nisin and lactic acid. For test sample preparation, the preservative solutions were added to raw deboned goat meat (chevon) cubes on glass petri plates, and mixed properly for 5 minutes at room temperature inside a biosafety cabinet, thereby ensuring uniform distribution of the preservatives. The test samples were evaluated at every alternate day up to 7 days for quality changes under refrigerated storage, in aerobic packaging. The preparation of control and treated raw chevon samples for refrigerated storage study is given in Fig. 1.

Physico-chemical characteristics of chevon samples

The pH of raw goat meat (chevon) was measured using a digital pH meter (pH Tutor, Eutech Instruments) with a combined glass electrode. The thiobarbituric acid reactive substances (TBARS) value was assessed through the distillation method [23]. The peroxide value (PV) and free fatty acid (FFA) levels were determined according to established protocols with appropriate modifications [24]. The extract release volume (ERV) was calculated following a standard procedure [25]. Additionally, the water activity (a_w) of the meat sample was evaluated using a portable digital a_w meter (Aqua Lab Dew Point a_w Meter, USA).

Microbiological analysis of chevon samples

The determination of total plate count (TPC), psychrophilic count, and coliform count of the chevon samples was carried out as per the standard methods of the American Public Health Association [26].

Color and odor score of raw chevon

A semi-trained panel of members comprising research scholars and scientists of the Division of LPT, ICAR-IVRI, Bareilly evaluated the visual color and odor scores of raw chevon by using the 5-point scale [27].

Statistical analysis

The experimental data were compiled and analyzed using both one-way and two-way ANOVA with IBM SPSS Statistics 20 software (SPSS Inc., NY, USA). Each parameter involved duplicate samples, and the entire experiment was conducted three times (n=6, except for sensory evaluations, which had n=18). Duncan's multiple range tests were applied to compare means for significant differences. Statistical significance was set at a 95% confidence level ($p<0.05$), and the analyzed data were organized into tables for interpretation.

RESULTS AND DISCUSSION

Proximate composition of raw chevon

The proximate composition of the raw chevon reveals a moisture content of 74.49%, 5.61% fat content, 19.43% protein and 0.98% ash content. These data were found to be in accordance with that reported by Baharuddin and Abdullah [28] and Webb [29].

Determination of concentration of crude extract for incorporation into chevon

The average weight of the dried curd supernatant was measured at 1.1 g per batch. To prepare a 10-fold concentrated crude extract (CE) with a concentration of 550 mg/mL, 2 mL of sterile distilled water (pH 7.0) was added to the dried curd supernatant. This solution was then diluted to create 5-fold (275 mg/mL), 4-fold (220 mg/mL), 3-fold (165 mg/mL), and 2-fold (110 mg/mL) concentrations. The antibacterial activities of these different concentrations of CE demonstrated significant differences ($p<0.05$) against standard bacterial strains (Fig. 2). The highest antibacterial

Table 1. Changes in physico-chemical properties of control and different treatment groups of raw chevon during refrigerated storage study.

Samples	Physico-chemical properties			
	1st day	3rd day	5th day	7th day
		pH		
Control (C)	5.71±0.03^{Ad}	5.82±0.03^{Ac}	5.98±0.02^{Ab}	6.18±0.01^{Aa}
T_1	5.68±0.02^{Ad}	5.77±0.02^{Ac}	5.88±0.01^{Bb}	5.97±0.02^{Ba}
T_2	5.66±0.02^{Ad}	5.82±0.03^{Ac}	5.96±0.02^{Ab}	6.14±0.04^{Aa}
T_3	5.69±0.02^{Ad}	5.78±0.01^{Ac}	5.87±0.02^{Bb}	6.04±0.02^{Ba}
		Thiobarbituric acid reactive substances		
Control (C)	0.48±0.02^{Ad}	0.99±0.04^{Ac}	1.72±0.05^{Ab}	1.98±0.03^{Aa}
T_1	0.32±0.01^{Cd}	0.62±0.02^{Cc}	0.91±0.01^{Cb}	1.19±0.03^{Da}
T_2	0.35±0.01^{BCd}	0.74±0.01^{Bc}	1.28±0.01^{Bb}	2.21±0.04^{Ba}
T_3	0.39±0.02^{Bd}	0.82±0.03^{Bc}	1.22±0.03^{Bb}	1.41±0.03^{Ca}
		Free fatty acid		
Control (C)	0.46±0.02^{Ad}	0.61±0.02^{Ac}	0.79±0.03^{Ab}	0.92±0.03^{Aa}
T_1	0.39±0.01^{Bd}	0.49±0.01^{Ccc}	0.58±0.01^{Cb}	0.74±0.01^{Ca}
T_2	0.40±0.01^{Bd}	0.51±0.01^{Cc}	0.63±0.01^{Bb}	0.85±0.01^{Ba}
T_3	0.45±0.02^{Ad}	0.57±0.01^{Bc}	0.67±0.01^{Bb}	0.83±0.01^{Ba}
		Peroxide value		
Control (C)	1.77±0.02^{Ad}	2.25±0.03^{Ac}	2.63±0.06^{Ab}	3.41±0.07^{Aa}
T_1	1.70±0.01^{Bd}	2.11±0.03^{Bc}	2.37±0.04^{Cb}	2.69±0.09^{Ca}
T_2	1.72±0.02^{Abd}	2.16±0.02^{ABc}	2.46±0.05^{BCb}	3.20±0.06^{Ba}
T_3	1.74±0.02^{Abd}	2.22±0.05^{Ac}	2.59±0.06^{ABb}	2.81±0.05^{Ca}
		Extract release volume		
Control (C)	47.63±0.28^{Ba}	44.53±0.19^{Bb}	31.45±0.16^{Cc}	25.77±0.06^{Cd}
T_1	47.78±0.38^{Ba}	45.28±0.29^{Ab}	35.33±0.27^{Ac}	28.22±0.23^{Ad}
T_2	48.95±0.20^{Aa}	45.20±0.17^{ABb}	31.03±0.21^{Cc}	22.33±0.23^{Dd}
T_3	46.93±0.26^{Ba}	43.68±0.25^{Cb}	34.42±0.25^{Bc}	27.45±0.23^{Bd}
		Water activity		
Control (C)	0.999±0.000^{Aa}	0.962±0.003^{Bb}	0.932±0.004^{Cc}	0.895±0.004^{Cd}
T_1	0.992±0.001^{Ba}	0.980±0.002^{Ab}	0.958±0.003^{Ac}	0.929±0.002^{Ad}
T_2	0.991±0.001^{Ba}	0.976±0.002^{Ab}	0.943±0.005^{BCc}	0.895±0.004^{Cd}
T_3	0.989±0.002^{Ba}	0.981±0.000^{Aa}	0.952±0.005^{ABb}	0.915±0.003^{Bc}

*Mean values with different superscripts in a column (capital letters) and a row (small letters) have significant differences ($p< 0.05$). T1 = Raw chevon mixed with 5-fold concentrated crude extract, T2 = Raw chevon mixed with 0.5% lactic acid, T3= Raw chevon mixed with nisin (10ppm), Control = chevon sample with no treatment, n= 6.

effect was noted in the 10-fold concentrated sample, while the activity declined in a concentration-dependent manner. The minimum antibacterial activity for both bacterial strains was identified in the 2-fold concentrated solution, and no clear zone of inhibition (ZOI) was observed in the unprocessed curd supernatant.

Preparation of chevon samples for storage life study

The quality assessment of the untreated control chevon sample (C), as well as samples treated with 5-fold concentrated crude extract (T1), 0.5% lactic acid (T2), and 10 ppm nisin (T3), was conducted during refrigerated storage at 4±1°C. All samples were packaged in low-density polyethylene (LDPE) bags (200 gauge) and evaluated every other day for a duration of 7 days under aerobic conditions.

Changes in physico-chemical characteristics

pH

pH is considered an important factor in assessing the storage life of meat, providing insights into its quality. In this study, the pH levels of the control sample (C) and T2 were significantly higher ($p<0.05$)

Table 2. Changes in microbial quality of test groups of raw chevon during refrigerated storage study.

Samples	Microbial quality			
	1st day	3rd day	5th day	7th day
	Total plate count (log_{10} cfu/g)			
Control (C)	5.39 ± 0.04^{Ad}	5.99 ± 0.03^{Ac}	7.36 ± 0.01^{Ab}	9.42 ± 0.01^{Aa}
T_1	5.20 ± 0.06^{Ad}	5.57 ± 0.05^{Cc}	6.09 ± 0.03^{Db}	7.23 ± 0.08^{Da}
T_2	5.26 ± 0.09^{Ad}	5.78 ± 0.05^{Bc}	7.02 ± 0.02^{Bb}	9.11 ± 0.01^{Ba}
T_3	5.23 ± 0.08^{Ad}	5.74 ± 0.02^{Bc}	6.92 ± 0.03^{Cb}	8.15 ± 0.05^{Ca}
	Coliform count (log_{10} cfu/g)			
Control (C)	2.53 ± 0.06^{Ad}	3.37 ± 0.05^{Ac}	4.39 ± 0.01^{Ab}	6.10 ± 0.02^{Aa}
T_1	2.18 ± 0.08^{Bc}	2.40 ± 0.10^{Cc}	2.91 ± 0.10^{Cb}	4.23 ± 0.08^{Ca}
T_2	2.30 ± 0.07^{Bd}	3.15 ± 0.06^{Bc}	4.28 ± 0.01^{Ab}	6.21 ± 0.02^{Aa}
T_3	2.19 ± 0.07^{Bd}	3.05 ± 0.06^{Bc}	3.78 ± 0.04^{Bb}	5.65 ± 0.04^{Ba}
	Psychrophilic count (log_{10} cfu/g)			
Control (C)	2.61 ± 0.04^{Ad}	3.73 ± 0.06^{Ac}	4.87 ± 0.03^{Ab}	5.94 ± 0.03^{Aa}
T_1	2.18 ± 0.08^{Bd}	3.05 ± 0.08^{Cc}	3.90 ± 0.06^{Cb}	4.80 ± 0.08^{Ca}
T_2	2.40 ± 0.10^{ABd}	3.48 ± 0.05^{Bc}	4.30 ± 0.04^{Bb}	6.02 ± 0.02^{Aa}
T_3	2.28 ± 0.11^{Bd}	3.20 ± 0.09^{Cc}	4.19 ± 0.05^{Bb}	5.56 ± 0.06^{Ba}

*Mean values with different superscripts in a column (capital letters) and a row (small letters) have significant differences ($p< 0.05$). T1 = Raw chevon mixed with 5-fold concentrated crude extract, T2 = Raw chevon mixed with 0.5% lactic acid, T3= Raw chevon mixed with nisin (10ppm), Control = chevon sample with no treatment, n= 6.

Table 3. Changes in sensory qualities of test chevon samples during refrigerated storage study.

Samples	Sensory qualities			
	1st day	3rd day	5th day	7th day
	Color score			
Control (C)	4.69 ± 0.07^{Aa}	4.24 ± 0.04^{ABb}	3.24 ± 0.04^{Ac}	2.29 ± 0.05^{Bd}
T_1	4.73 ± 0.07^{Aa}	4.34 ± 0.04^{Ab}	3.27 ± 0.04^{Ac}	2.86 ± 0.03^{Ad}
T_2	4.57 ± 0.06^{Aab}	4.26 ± 0.04^{Ab}	3.21 ± 0.05^{Ac}	2.23 ± 0.03^{Bd}
T_3	4.48 ± 0.06^{Ba}	4.14 ± 0.03^{Bb}	3.15 ± 0.02^{Ac}	1.99 ± 0.03^{Cd}
	Odour score			
Control (C)	4.39 ± 0.03^{Aa}	4.13 ± 0.03^{Ab}	3.11 ± 0.03^{Bc}	2.02 ± 0.03^{Cd}
T_1	4.41 ± 0.03^{Aa}	4.05 ± 0.02^{Bb}	3.55 ± 0.03^{Ac}	3.02 ± 0.03^{Ad}
T_2	4.43 ± 0.03^{Aa}	3.99 ± 0.03^{Bb}	2.97 ± 0.04^{Cc}	1.92 ± 0.04^{Dd}
T_3	4.41 ± 0.04^{Aa}	4.17 ± 0.03^{Ab}	3.17 ± 0.03^{Bc}	2.24 ± 0.02^{Bd}

*Mean values of scores on a 5-point Hedonic scale (1= extremely undesirable and 5= extremely desirable) with different superscripts in a column (capital letters) and a row (small letters) have significant differences ($p< 0.05$). T1 = Raw chevon mixed with 5-fold concentrated crude extract, T2 = Raw chevon mixed with 0.5% lactic acid, T3= Raw chevon mixed with nisin (10ppm), Control = chevon sample with no treatment, n = 18.

than those of T1 and T3 from days 5 to 7. However, no significant differences ($p>0.05$) were found in the average pH values among the control and treatment groups from days 1 to 3 during refrigerated storage (Table 1). The pH values observed in this study fall within an acceptable range and align with previous researches [32, 33], who reported similar increases in pH over time when examining buffalo meat and ground poultry meat, respectively.

TBARS value

TBARS is a commonly used indicator for assessing the degree of secondary lipid oxidation in meat. In this study, the mean TBARS values (mg MDA/Kg) for all samples exhibited a consistent increase from day 1 to day 7 of storage. Notably, T1 maintained the significantly lowest TBARS values throughout the storage period (Table 1). These findings are consistent with the results reported by Sharma and Sen [34],

Fig. 1. Control and treated raw chevon samples used during refrigerated storage study.

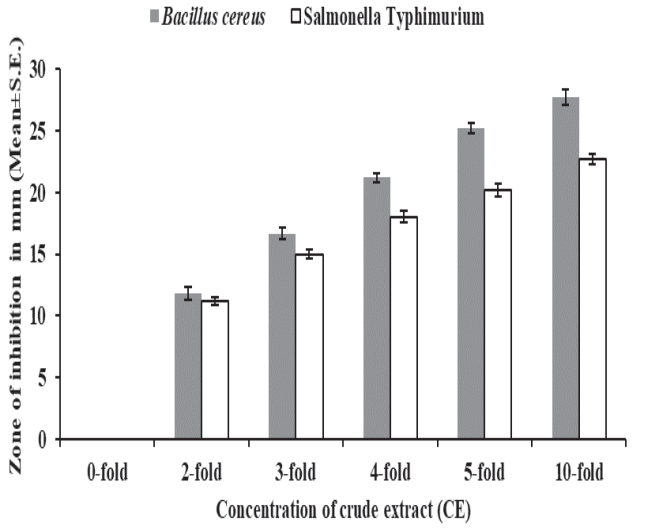

Fig. 2. Graph showing antibacterial activities against *Bacillus cereus* and *Salmonella* Typhimurium according to different concentrations (2, 3, 4, 5 and 10-fold) of the crude extract (CE).

who noted a substantial rise in TBA values from 0.80 ± 0.01 MDA/kg to 1.99 ± 0.22 MDA/kg in buffalo meat stored in ice. Similarly, Kandeepan and Biswas [33] observed an increase in TBA values during the refrigerated storage of buffalo meat, concluding that TBA levels tend to rise with extended storage times under refrigeration and freezing conditions. Comparable results were also documented by other workers [27, 35], who investigated the effects of tocopherol acetate and carnosine pre-blending on ground chevon and buffalo meat, respectively, during storage at 4±1°C.

Free fatty acid (FFA) content

The treated samples exhibited significantly ($p<0.05$) lower free fatty acid (FFA) content compared to the control sample (Table 1). Throughout the storage period, there was a notable increasing trend in FFA levels. Specifically, the T1 sample consistently maintained lower FFA content during storage ($p<0.05$). Previous research has indicated that the FFA content in minced beef ranges from 0.38% to 1.74%, with a maximum acceptable limit of 1.8% during storage [36]. Similar increasing trends in FFA levels have also been observed in buffalo meat [37] and goat meat [35] during 9 days of refrigerated storage.

Peroxide value (PV)

Peroxide value is a valuable metric for assessing the degree of lipid, fat, and oil oxidation, as it directly quantifies lipid peroxides, the main products of lipid oxidation [38]. In this study, we found that the peroxide values were significantly lower in the treated samples compared to the control ($p<0.05$). However, there was a significant linear increase in peroxide values throughout the refrigerated storage period (Table 1). These findings align with the research conducted by Rao and Kowale [39], which showed that the peroxide value in control goat meat was higher than in samples treated with curry leaf powder from day 1 to day 9. Additionally, our results corroborate the work of Verma and Sahoo [35], who reported a positive correlation between peroxide values and TBARS levels in chevon during refrigerated storage.

Extract release volume (ERV)

Extract release volume (ERV) refers to the amount of free water released by meat during storage and is closely linked to microbial spoilage; higher spoilage correlates with lower ERV [40]. In this study, we observed a declining trend in ERV across all samples as the storage duration increased. Concurrently, microbial counts, including total plate count (TPC), coliform, and psychrophilic count, showed an upward trend, highlighting the relationship between ERV and microbial spoilage. Despite the overall decrease in ERV across all treatment groups, the values were significantly higher ($p<0.05$) in the treated samples compared to the control (Table 1). Previous research indicated that an ERV of 25 mL serves as a rejection threshold [25]. Similar results have been reported previously for refrigerated chevon [41, 42].

Water activity (a_w)

There was a significant difference ($p<0.05$) in water activity (aw) between the control and treatment samples from days 1 to 3. However, from days 5 to 7, no significant differences ($p>0.05$) were observed between T1 and T3, as well as between T2 and the control. At the end of the storage period, T2 and the control exhibited significantly lower a_w values ($p<0.05$) compared to T1 and T3. Overall, the a_w of all samples demonstrated a decreasing trend from day 1 to day 7 (Table 1). These findings are consistent with research on the effects of salting, air drying, and aging processes on chevon quality. Additionally, Chatli [44] reported a reduction in the a_w of raw chevon wrapped in edible film, decreasing from 0.991 to 0.902 after 7 days of refrigerated storage. In contrast, both Chatli [44] and Kandeepan *et al.* [45] found no significant differences in the a_w of buffalo meat keema among treatment groups stored under chilled conditions.

Changes in microbiological quality

Table 2 indicates the average total plate count (TPC), psychrophilic and coliform counts (log10 cfu/g) for both control and treated chevon samples throughout the storage study.

Total plate count (TPC)

Total plate count (TPC) is a key measure for assessing the microbial quality and safety of food products [46]. In this study, the microbiological quality of raw chevon showed significant variation ($p<0.05$) with different antimicrobial treatments during storage (Table 2). By day 7, T1 exhibited the lowest TPC, while the control showed the highest. Across all test samples, the TPC of raw chevon increased significantly ($p<0.05$) with prolonged refrigerated storage (Table 2). On day 1, there were no significant differences ($p>0.05$) in TPC among the samples. The rate of increase in TPC was significantly lower for T1 compared to the control and other treatments, likely due to the antimicrobial properties of the crude extract (CE) derived from Indian curd. From days 5 to 7, the control sample had a significantly higher TPC, followed by T2, while T1 and T3 maintained a significantly lower microbial load.

These results align with privious findings [44], which indicated that the TPC of control goat meat chunks ranged from 6.51 to 9.50 log10 cfu/g over 7 days of refrigerated storage. Similarly, Das *et al.* [39] reported a TPC of 4.57 to 7.01 log10 cfu/g for control and moringa leaf powder-treated ground goat meat samples stored under refrigeration for 9 days. Kandeepan and Biswas [47] noted an increase in TPC in buffalo meat over 4 days of chilling. Verma and Sahoo [35] also documented a rise in TPC from 4.17 log10 cfu/g to 7.65 log10 cfu/g by the ninth day during their investigation of tocopherol acetate pre-blending on ground chevon.

Coliform count

The presence of coliform bacteria indicates potential fecal contamination and inadequate hygiene practices during the slaughter and processing of meat [48]. In this study, the coliform levels in raw goat meat (chevon) varied significantly ($p<0.05$) depending on the antimicrobial treatments applied during storage, with the lowest counts found in the treatment group T1 and the highest in the control group after seven days. Across all groups, there was a notable increase in coliform counts as the refrigerated storage duration extended ($p<0.05$). However, the rate of increase was significantly lower in T1 compared to the control and other treatment groups (Table 2).

Notably, the Food Safety and Standards Authority of India (FSSAI) and the USDA-FDA have not established specific limits for overall coliform counts (including species such as *Escherichia*, *Enterobacter*, *Citrobacter*, and *Klebsiella*) in raw meat products, though they do provide a standard for *E. coli* counts in raw meat, which should be below 5 x 10^2 cfu/g. On day 0 of the study, the average coliform counts in the samples ranged from 2.18 to 2.53 log cfu/g. The increased coliform counts observed over the storage period are likely attributed to contamination during slaughter or from unsanitary equipment and surfaces used throughout processing and storage. In line with these results, a separate assessment of raw meat from local markets in Dharan, eastern Nepal, found an average coliform count of 6.37 log cfu/g in goat meat [49]. Additionally, another study reported a rise in coliform levels from 3.53 to 7.10 log cfu/g over a week of refrigerated storage for goat meat, while a similar increase was noted in buffalo meat stored at 4±1°C [47].

Psychrophilic count

Refrigerated meat products are particularly vulnerable to the proliferation of psychrophilic spoilage bacteria and pathogens. Among these, *Pseudomonas* spp. is one of the primary microorganisms responsible for spoilage in refrigerated meat products [50]. The psychrophilic counts in raw goat meat (chevon) samples

varied significantly ($p<0.05$) with both the duration of storage and the treatments applied. Notably, the T1 sample consistently exhibited a significantly lower psychrophilic count throughout the entire storage period. A previous study indicated that psychrophilic counts in ground goat meat increased from 3.92 to 6.39 log10 cfu/g over a nine-day storage period [39]. Similarly, Kandeepan and Biswas reported rising psychrophilic counts during the chilled storage of buffalo meat [51].

Changes in sensory quality

The appearance and odor of fresh meat are key factors influencing its acceptability [31]. During the storage period, there was a notable ($p<0.05$) decrease in the color scores of all goat meat (chevon) samples. On day 1, no significant differences ($p>0.05$) were observed in color and odor between control and treated samples, except for T2, which showed a lower color score (Table 3). As storage continued, a significant deterioration in visual color was noted. These results align with findings regarding tocopherol-treated ground chevon [35] and on the on the refrigerated storage of ground buffalo meat [27].

The odor scores also declined significantly ($p<0.05$) in a linear fashion as storage time increased (Table 3). The goat meat retained its desirable odor for up to five days, after which the quality diminished between days five and seven. Similar trends in odor deterioration have been documented in refrigerated ground buffalo meat [27]. This observation is consistent with flavor changes noted in vacuum-packed ground buffalo meat [52], where an increase in off-odors was also reported as the storage period extended [53]. The sharp decline in flavor could be linked to the release of fatty acids, fat oxidation, and a rise in microbial load [54].

CONCLUSION

The findings indicated that the chevon sample treated with CE (T1) remained acceptable for up to seven days, while the other samples were only acceptable up to five days. The comparative analysis clearly demonstrated that CE was the most effective among the preservatives tested, successfully prolonging the shelf life of raw chevon while maintaining acceptable physical, chemical, microbial, and sensory qualities during refrigerated storage at 4±1°C. Therefore, CE derived from Indian curd could serve as a viable alternative to traditional chemical preservatives for extending the shelf life of meat products.

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