Research Article

Journal of Meat Science
Year 2026, Vol.21 (2)

Storage Stability of Functional Restructured Goat Meat Blocks Stored in Aerobic Packaging under Refrigerated Conditions

Singh Harmanbir[1], **Pavan Kumar**[1*], **Rajesh V Wagh**[1] and **Chanchal Singh**[2]

[1]Department of Livestock Products Technology, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana 141004

[2]Department of Animal Nutrition, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana 141004

[3]Department of Veterinary Physiology and Biochemistry, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab 141004

***Correspondence:** <pavankumar@gadvasu.in>

Submission: 26 November 2025 **Acceptance:** 3 June 2026

DOI: https://doi.org/10.48165/jms.2026.21.02.04

ABSTRACT

This study assessed the storage stability of functional restructured goat meat blocks (RGMB) stored in aerobic packaging under refrigerated conditions (4±2 °C). Three RGMB samples, viz., control (C-RGMB without jamun seed powder and papaya rind powder), positive control (PC-RGMB with 3% jamun seed powder), and treatment (T- 3% jamun seed powder and 2% papaya rind powder) were prepared and developed blocks were stored in low-density polyethylene (LDPE) bags under aerobic packaging under refrigeration (4±2 °C). The samples were analyzed for pH, lipid oxidation parameters, microbial quality, and sensory evaluation at 7-day intervals until 28 days. The pH value of RGMB showed an increasing trend with the elapse of storage time, with the lowest value recorded at 0 days and the highest pH value at 28 days for the respective RGMB samples. Thiobarbituric acid reactive substances (TBARS) value of all RGMB samples (C, PC, and T) increased significantly ($p < 0.05$) with increasing storage period from 7 days onwards. The SPC count of RGMB increased significantly with storage duration, and each sample reached its highest value after 28 days. Throughout the storage, T samples recorded the lowest SPC count, followed by PC and C, with the following trend: T < PC < C. From 14 days onward, a significantly higher overall acceptability was recorded for T samples as compared to PC and C samples.

Keywords: Restructured meat; lipid oxidation; microbial quality; sensory attributes; aerobic packaging

INTRODUCTION

Goat meat is a very popular meat worldwide and is a rich source of high-quality animal protein, a desirable lipid and mineral profile, lower cholesterol content (Umaraw et al. 2017; Watkins et al. 2021). It is not associated with any social or religious taboos. Goats are highly adaptable and prolific small ruminants that exhibit a remarkable ability to produce meat and milk even under harsh climatic conditions with limited resources (Kumar et al. 2023). Goats are highly susceptible to various preslaughter stressors, managemental conditions, as well as the slaughter of aged or culled animals, resulting in the production of goat meat that exhibits higher toughness and stringiness (Kumar et al. 2024). This has a significant impact on nutritive value, marketability, and consumer acceptance (Sobri et al. 2023).

Various technological interventions, such as comminution, restructuring, ultrasonication, marination, and tenderizing, are applied in meat processing to improve the tenderness and acceptability of meat products prepared from less tender meat obtained from culled or spent animals. Restructured meat products are categorized as intermediate meat products, falling between muscle steaks and traditional burgers (Sheard 2002; Singh et al. 2026).

Restructuring is highly efficient technology in utilizing tough and less tender meat, trimmings, and low-value meat cuts to produce more valuable and acceptable meat products through the application of massaging, blade tenderization, or tumbling (Gadekar et al. 2015). Due to the high level of processing, these products are more prone to lipid oxidation and discolouration, thus various natural antioxidants, plant extracts, and vegetable powders are added to improve the oxidative stability and nutritive quality (Gadekar et al. 2014, 2015, 2017; Reddy et al. 2013; Sharma et al. 2014; Ahmad et al. 2021; Talukdar et al. 2013). Jamun seed powder is high in tannins, phenolic acids, flavonoids, phenolics, terpenoids, phloroglucinol derivatives, fibre, and mineral content; hence, its incorporation in meat could enhance oxidative stability (Tak et al. 2022). Similarly, papaya rind contains high levels of papain and phenolic compounds, which could improve the antioxidant potential and tenderization of tough meats, such as goat meat.

The packaging conditions, including packaging materials, type of packaging, and storage temperature, play a vital role in preserving meat quality and extending shelf life. Due to its high nutrient quality, high moisture content, and inherently low antioxidant levels, meat is highly susceptible to spoilage through the multiplication of spoilage and pathogenic microorganisms, as well as oxidative changes in lipids and proteins (Awad et al. 2021; 2022). Thus, the present study was undertaken to evaluate the oxidative stability of functional restructured goat meat blocks stored in aerobic packaging under refrigerated conditions (4±2 °C)

MATERIALS AND METHODS

Two male goats (beetle breed, approximately 1.5-2 years old, weighing 25-30 kg) were scientifically slaughtered at the experimental slaughterhouse of the department, following standard protocols. The carcasses were chilled overnight and deboned manually. The deboned meat was packed in low density polyethylene (LDPE) bags and stored at -18°C until further use. Before processing, the frozen meat was thawed in the refrigerator at 4 ± 2 °C overnight and manually cut into uniform cubes of approximately 1–1.5 cm. Various ingredients, as detailed in Table 1, were added to the goat meat cubes, thoroughly mixed, and conditioned under refrigeration for 5 hours. A total of three batches of samples were prepared viz., Control (C-without jamun seed powder and papaya rind powder), Positive Control (PC-with 3% jamun seed powder but no papaya rind powder), and T (3% jamun seed powder and 2% papaya rind powder). The conditioned mixtures were transferred to a vacuum tumbler (Promarks Vac. Co. Ltd, Taiwan) and tumbled under vacuum for 3.5 hours until tacky exudates were formed. The resulting goat meat batter was packed into aluminium moulds and autoclaved at 15 psi for 15 minutes.

Table 1: Formulation for the preparation of functional restructured goat meat blocks (RGMB)

Ingredients	Control	PC	T
Goat meat	81.0	78.0	76.0
Water	10.0	10.0	10.0
Condiments	5.0	5.0	5.0
Spices	2.0	2.0	2.0
Salt	1.65	1.65	1.65
STPP	0.25	0.25	0.25
Sodium nitrite	0.10	0.10	0.10
JSP	-	3.0	3.0
PRP	-	-	2.0

PRP- Papaya rind powder, JMS-jamun seed powder, Control- product without PRP and JMS, PC- product with 3% JMS, T- product with 3% JMS and 2% PRP, STPP- Sodium tetrapolyphosphate

The cooked blocks were tempered at ambient temperature and then chilled overnight at 4 ± 2 °C. The set products were sliced to a thickness of 8 mm using a slicer (Sirman, Model Auto M 300 VV, Italy). The products were aerobically packaged in LDPE films (100 gauge) by using a packaging machine (Ramon Packaging Machine: VP-580 A Model, type 19/S/CL, Germany) and analysed for pH, lipid oxidation parameters, microbial quality, and sensory attributes at a regular interval of 7 days for 28 days under refrigeration (4 ± 2 °C).

Analytical procedures

The pH of developed RGMB was assessed with digital pH meter (SAB 5000, LABINDIA, Mumbai). Before estimation, it was calibrated by using standard buffer solutions (4.0, 7.0, and 9.0 pH). The lipid oxidation parameters, such as thiobarbituric acid reacting substances (TBRAS) (Witte et al. 1970), free fatty acid (FFA), and peroxide value (PV) (Koniecko 1979), were assessed to evaluate the oxidative stability of RGMB.

The microbiological quality of RGMB was assessed by noting standard plate count (SPC), coliform count, and psychrophilic count according to the method outlined by APHA (1984). The RGMB sample and serial dilutions for microbial estimation were undertaken in aseptic conditions, near flame in a pre-sterilised horizontal laminar flow apparatus (Model Rescholar, M. No. RH-58-C3, Ambala Cantt, India).

A sensory panel comprising seven experienced in-house members evaluated the sensory attributes of RGMB heated in a microwave oven for 1.5 min. The RGMB samples were assessed for appearance and colour, flavour, juiciness, tenderness, and overall acceptability using an 8-point descriptive scale, where higher scores indicated greater intensity or desirability of the attribute (ISO 3972:2011, SS-EN ISO 8586:2014). Each sensory evaluation was performed in triplicate (n =21) (Snedecor and Cochran 1989).

All experimental data were expressed as mean values accompanied by their respective standard errors (Mean ± SE) to ensure accurate representation of variability among replicates. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software, version 26 (SPSS Inc., Chicago, IL, USA). The data recorded during the experiment were analyzed using univariate general linear models (GLM) on SPSS 26 software (IBM Corporation, USA) and presented as mean values with standard errors (Mean ± SE). The data were analyzed using the main effects of incorporating JMS and PPR, storage days, and their two-way interactions. The significant difference between sample means was assessed using a Two-Way Analysis of Variance (ANOVA) using Duncan's Multiple Range Test (DMRT) at 5% level ($p < 0.05$) with a sample size of 6 (n = 6).

RESULTS AND DISCUSSION

The pH value of RGMB in aerobic packaging stored under refrigeration conditions (4±2 °C) is presented in Table 2. The pH value of RGMB showed an increasing trend with increasing storage duration, with the lowest value recorded at 0 days and the highest pH value at 28 days for the respective RGMB samples. Initially, the pH did not differ significantly ($p > 0.05$) up to 7 days; thereafter, a significant ($p < 0.05$) increase in pH was observed in all samples. The pH of the Control samples on day 28 was recorded as significantly higher ($p < 0.05$) than the pH on day 21 of storage. Among the treatments, the pH of the treated samples was recorded as significantly lower ($p<0.05$) than that of the C and PC samples from 14 days onwards of refrigerated storage. The initial lower pH of T as compared to C and PC samples could be attributed to the addition of papaya rind paste in the samples. The increase in pH during refrigerated storage of RGMB samples could be attributed to a rise in microbial load, which consequently causes protein denaturation and the accumulation of its metabolites. Similar findings of increasing pH were also observed by Kumar et al. (2018a) during storage of pork patties incorporated with sapota powder, watermelon rind extract in pork patties (Kumar et al. 2018b), and restructured spent hen meat slices prepared by using fig powder (Kantale et al. 2019).

Table 2: pH and lipid oxidation parameter of restructured goat meat blocks (RGMB) stored at refrigeration under aerobic packaging. (Mean ± S.E.)

Treatments	Days				
	0	7	14	21	28
pH					
C	6.38±0.03^{aB}	6.41 ±0.02^{aB}	6.45±0.02^{abC}	6.49±0.03^{bC}	6.56±0.04^{cC}
PC	6.22±0.02^{aA}	6.25 ±0.01^{aA}	6.32±0.02^{bB}	6.38±0.02^{bcB}	6.48±0.07^{cB}
T	6.19±0.02^{aA}	6.21 ±0.02^{aA}	6.24±0.02^{abA}	6.30 ±0.05^{bcA}	6.36±0.02^{cA}
FFA (% Oleic acid)					
C	0.125 ±0.004^{a}	0.144 ±0.004^{bB}	0.298±0.03^{cB}	0.428 ±0.04^{dC}	0.575±0.04^{eC}
PC	0.122 ±0.005^{a}	0.134±0.004^{abAB}	0.272±0.04^{bAB}	0.397±0.03^{cB}	0.568±0.06^{dB}
T	0.120 ±0.002^{a}	0.129 ±0.003^{abA}	0.265±0.03^{bA}	0.381 ±0.02^{cA}	0.482±0.05^{dA}
PV (meq/kg)					
C	3.782±0.03^{a}	5.01±0.07^{bB}	6.37±0.20^{cC}	8.923±0.23^{dC}	10.92±0.24^{eC}
PC	3.718±0.08^{a}	4.91±0.09^{bAB}	5.87±0.21^{cB}	7.24 ±0.15^{dB}	10.71±0.24^{eB}
T	3.689±0.05^{a}	4.79±0.10^{bA}	5.62±0.30^{cA}	7.10 ±0.19^{dA}	8.65±0.15^{eA}

Means with different superscripts differ significantly ($p < 0.05$) lowercase letters (a, b, c, ...) indicate differences within rows, while uppercase letters (A, B, C, ...) indicate differences within column; n = 6 for each treatment.

PRP- Papaya rind powder, JMS-jamun seed powder, Control- product without PRP and JMS, PC- product with 3% JMS, T- product with 3% JMS and 2% PRP

In the present study, lipid oxidation was measured by assessing the thiobarbituric acid reactive substances (TBARS), free fatty acids (FFA), and peroxide value (PV) of RGMB upon refrigerated storage. These parameters (TBARS, FFA, and PV) for all RGMB samples studied in the present study showed increasing trends with increasing storage period (Figure 1 and Table 2).

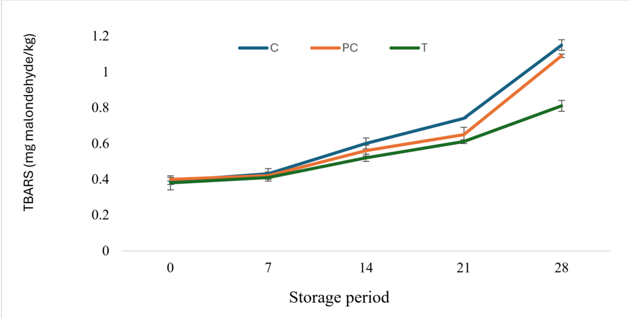

Figure 1. TBARS value of restructured goat meat blocks (RGMB) stored at refrigeration under aerobic packaging

The TBARS value of all RGMB samples (C, PC, and T) increased significantly ($p<0.05$) with advancing storage days from 7 days onward. TBARS values of 0 and 7 days were recorded as comparable and did not differ significantly ($p > 0.05$) (Figure 1). The TBARS value of all samples on 28 days was recorded as the highest compared to their respective samples at 21 days, which in turn was significantly ($p<0.05$) higher than their corresponding samples at 14 days. A higher rate of increase in TBARS value was observed in control and PC samples, whereas it was recorded as the lowest for T samples. This could be due to polyphenolic compounds in papaya rind powder, which exert an antioxidant effect. The antioxidant activity of different fruit powders in the food system due to the presence of total phenols, flavonoids, ortho-diphenols, tannins, and anthocyanins was also reported (Harzallah et al. 2016). Pathak et al. (2019) reported a higher content of polyphenolic compounds in papaya fruit rind. Jamal et al. (2017) noted 1735.1 mg/L GAE total phenolic content in the papaya fruit peel and attributed the strong antioxidant potential of papaya fruit peel to its high total phenolics. Similarly, Marina and Noriham (2014) reported strong antioxidant activity of papaya peel extract, which contains high phenolic compounds such as catechin, epicatechin, and kaempferol, with a FRAP value of 1200 ppm, comparable to the BHT/BHA concentration of 200 ppm. Authors (Marina and Noriham 2014) also reported a potent inhibition of TBA formation with the application of papaya fruit peel extract. These bioactive polyphenolics exert antioxidant potential. Furthermore, there has been an increase in microbial population upon refrigerated storage, and several published studies have documented a positive correlation between microbial load and TBARS (Raja et al. 2014; Kumar et al. 2018a, b). (Figure 1)

(PRP- Papaya rind powder, JMS-jamun seed powder, Control- product without PRP and JMS, PC- product with 3% JMS, T- product with 3% JMS and 2% PRP**)**

The FFA and PV of RGMB increased with the passage of storage duration (Table 2). However, the increases in FFA and PV were notably lower in T samples than in control and positive control samples throughout the storage study. The FFA and PV values of the control sample were the highest among the other samples throughout the entire storage period. Among the samples, the FFA value of all samples were recorded comparable at the start of the storage study. However, on day 7, the FFA value of T was recorded as significantly lower than that of C. On days 21 and 28 of storage, the FFA value of T was recorded significantly ($p < 0.05$) lower than PC, which in turn was considerably lower than that of C. The lower FFA and PV values in the T samples could be attributed to the antioxidant and antimicrobial effects of the polyphenols present in the papaya rind powder used in the present study.

However, it should be noted that throughout the study, lipid oxidation parameters remained lower in PC than in C samples, which could be attributed to the incorporation of jamun seed powder into the PC samples. Tak et al. (2022) and Kumar et al. (2022) reported higher levels of bioactive compounds, including phenols, flavonoids, alkaloids, tannins, triterpenoids, and saponins, in jamun seed powder, which exhibit antioxidant and antimicrobial effects.

The microbial count of RGMB recorded an increased value with the advancement of storage period (Figure 2 and Table 3). This rate of increase in microbial count has crucial implications in the storage stability and quality attributes of stored RGMB. The SPC count of RGMB increased significantly ($p<0.05$) with increasing storage duration, and the SPC count of each sample reached its highest value after 28 days of storage (Fig 2). Within groups, no significant difference ($p > 0.05$) was observed on day 0 of storage. Throughout the storage, T samples recorded the lowest SPC count, followed by PC and C, with the following trend: T < PC < C. Within the group, the SPC of T on day 7 was significantly lower than PC and C, whereas on day 14, the SPC of T was significantly lower than PC, which in turn had substantially lower SPC than C samples. The comparatively lower microbial count for PC and T samples could be due to the antibacterial activity of the phenolic compounds present in the jamun seed and papaya rind powder. Furthermore, the comparatively lower pH of the T sample also contributed to its lower microbial load throughout the storage of these samples. This could be due to the increase in cell injury and the extension of the log phase of the microbial growth cycle, as observed by Kumar et al. (2018b) in pork patties formulated by incorporating watermelon rind extract. (Figure 2)

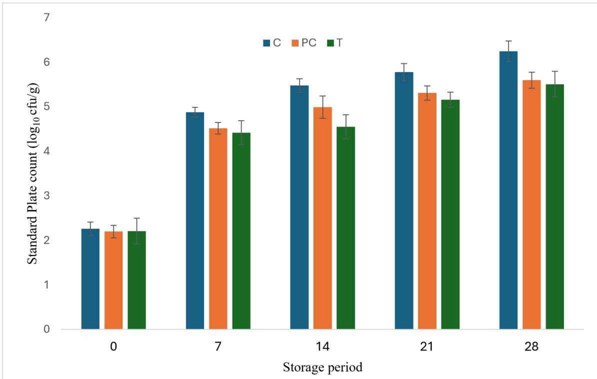

Figure 2. Standard Plate count (log10 cfu/g) of restructured goat meat blocks (RGMB) stored at refrigeration under aerobic packaging

(PRP- Papaya rind powder, JMS-jamun seed powder, Control- product without PRP and JMS, PC- product with 3% JMS, T- product with 3% JMS and 2% PRP**)**

Coliforms were detected on day 21 in all RGMB and thereafter increased ($p<0.05$) with increasing storage duration. The lower coliforms in T1 might be due to the antimicrobial effect of PRP. Psychrophiles were recorded on the 14th day of storage in all RGMB. Afterward, a significant ($p<0.05$) increase in psychrophile count was recorded in all samples. The initial absence of psychrophilic count during refrigerated storage could be due to the lower metabolic rate of these microbes, leading to an extended lag phase (Kantale et al. 2019). Similar to our findings, Gadekar et al. (2014) and Gupta and Sharma (2017) reported the presence of psychrophiles in restructured meat products after 21 days of aerobic storage at refrigerated temperatures. The detection of psychrophiles and coliforms after an initial absence could be due to the fact that bacteria generally require a lag phase before entering the log phase of active multiplication. Gupta and Sharma (2017) also reported similar findings in restructured spent hen meat slices. On the last day of storage, the lowest microbial count was noted in T samples, while the highest count was observed in the control.

Lohidas et al. (2015) also reported the antimicrobial activity of *Carica papaya* leaf, fruit, and seed extracts, attributing it to the presence of saponins, tannins, steroids, alkaloids, and flavonoids in these extracts. Prasetya et al. (2018) isolated active compounds with antimicrobial properties from *Carica papaya* and noted higher concentrations of flavonoids and alkaloids. Furthermore, authors (Prasetya et al. 2018) also reported potent inhibition of both Gram +ve and Gram -ve bacteria, but no antifungal properties, by these compounds. Similarly, Muhamad et al. (2017) also reported the in vitro antimicrobial activity of papaya peel extract against *Clostridium perfringens, Corynebacterium diphtheriae*, *Streptococcus pneumoniae*, and *Bacillus subtilis*. The petroleum ether extract of papaya peel contained 28 compounds, including higher concentrations of fatty acids, esters, alkanes, tocopherols, and sterols. 9,12,15-octadecatrienoic acid. The lower microbial load in PC samples as compared to control samples might be due to the presence of phenolic compounds in jamun seed powder. Balyan and Sarkar (2017) also reported the phenolic compounds in jamun seeds. Tak et al. (2022) also documented the presence of several bioactive compounds in jamun seed, exerting preservative effects such as terpenoids, hydrolysable tannins, flavonoids, phenolic acids, phloroglucinol derivatives, and saponins. Similarly, the antibacterial activity of jamun seed was also observed by Patel et al. (2012) and Bari et al. (2024).

Table 3: Microbiological quality of restructured goat meat blocks (RGMB) stored at refrigeration under aerobic packaging. (Mean ± S.E.)

Treatments	Days				
	0	7	14	21	28
Coliform (log_{10} cfu/g)					
C	-	-	-	1.75 ± 0.11^{aB}	1.99 ± 0.14^{bB}
PC	-	-	-	1.42 ± 0.13^{aA}	1.81 ± 0.17^{bAB}
T	-	-	-	1.38 ± 0.12^{aA}	1.71 ± 0.08^{bA}
Psychrophilic (log_{10} cfu/g)					
C	-	-	1.73 ± 0.156^{aB}	2.34 ± 0.16^{bB}	2.81 ± 0.13^{cB}
PC	-	-	1.89 ± 0.188^{aB}	2.12 ± 0.09^{abB}	2.51 ± 0.31^{bB}
T	-	-	1.51 ± 0.150^{aA}	2.08 ± 0.21^{abA}	2.35 ± 0.201^{bA}

Means with different superscripts differ significantly ($p < 0.05$) lowercase letters (a, b, c, ...) indicate differences within rows, while uppercase letters (A, B, C, ...) indicate differences within column; n = 6 for each treatment.

PRP- Papaya rind powder, JMS-jamun seed powder, Control- product without PRP and JMS, PC- product with 3% JMS, T- product with 3% JMS and 2% PRP

Sensory attributes play a very crucial role in the marketability and acceptability of meat products. In the present study, after opening the packets of RGMB, the flavour emanating from the packets was carefully assessed. If any abnormal development, such as sliminess, colour changes, or off-flavour, was observed, these packets were not tasted, and only visual sensory analysis was conducted. The sensory panellists noted a significant deterioration in the flavour of the control on the 28th day of storage; therefore, the control RGMB was not considered for sensory evaluation on the last day of storage.

Sensory parameters of RGMB exhibited a decreasing trend with increasing storage duration (Table 4). The appearance and colour score decreased with the advancement of the storage period. On the 14th day, these attributes were significantly ($P < 0.05$) lower than on the 0th and 7th days of storage for PC and T, whereas for C, a significant decrease was observed with the advancement of storage duration. Among treatments, on day 0, the appearance and colour score for C were significantly higher than those for T and PC samples, whereas on day 7, these values were comparable. From day 13, significantly ($p<0.05$) higher values for appearance and flavour were noted in T samples as compared to C and PC. This could be attributed to the presence of polyphenolic compounds, which resulted in the modification of the colour of RGMB, thus reducing the appearance and colour value initially. The better retention of the appearance and flavour score for the T sample could be attributed to the antioxidant and antimicrobial properties exhibited by the papaya rind powder. A similar decrease in the appearance and colour score of restructured spent hen meat slices was also reported by Gupta and Sharma (2017), attributed to lipid oxidation and pigment leading to non-enzymatic browning. Furthermore, surface dehydration in aerobic packaging also played a role in decreased appearance and colour score. Sudheer et al. (2011) also reported reduced appearance upon increased storage period in restructured chicken meat blocks.

Flavour scores of T samples were recorded significantly (P<0.05) higher than those of C samples from 14 days of storage onwards; before that, the flavour scores of all samples exhibited comparable values. A decrease in flavour score might be due to the gradual loss of volatile flavour compounds during aerobic storage (Bhat et al. 2015). Furthermore, the decrease in flavour scores of the control could also be attributed to rapid microbial growth and oxidative changes, consequently releasing foul odour from these samples. These findings align with findings on microbial quality and lipid oxidation parameters of the present study (Table 2 and Table 3).

The juiciness and tenderness scores followed a decreasing trend, with the lowest value of all samples recorded on the last day of storage (28 days) compared to their respective values at the beginning of the experiment (day 0). The juiciness of T sample was recorded significantly higher compared to PC and C samples from day 21 onwards. This gradual loss in these parameters might be caused by protein denaturation, which leads to alterations in disulfide bonds. Singh et al. (2015) also documented decreasing juiciness and tenderness scores of chicken cutlets. Malav et al. (2013) also noted decreased tenderness and juiciness scores during storage in restructured chicken meat blocks extended with sorghum flour and potato.

The overall acceptability of RGMB followed a decreasing trend upon storage. A significant ($P < 0.05$) decrease in overall acceptance of all samples was observed with the increase in storage duration. On day 0, the overall acceptability of T was significantly lower than that of C samples, whereas on day 7, all these values were recorded as comparable without exhibiting any significant difference. From 14 days onward, a significantly higher overall acceptability was recorded for T samples as compared to PC and C samples. On the last day of storage, the T samples had an overall acceptability score of 6.11, which is considered under the good category, whereas for PC samples, it was noted to be 5.85, under the poor to good category.

Table 4: Sensory attributes of restructured goat meat blocks (RGMB) stored at refrigeration under aerobic packaging. (Mean ± S.E.)

Treatments	Days				
	0	7	14	21	28
Appearance and colour					
C	7.25 ± 0.03^{dB}	7.05 ± 0.04^{c}	6.85 ± 0.09^{bA}	6.01 ± 0.06^{aA}	NP
PC	7.16 ± 0.08^{dA}	7.09 ± 0.08^{cd}	6.82 ± 0.11^{cA}	6.24 ± 0.06^{bB}	5.65 ± 0.13^{aA}
T	7.15 ± 0.16^{dA}	7.03 ± 0.08^{cd}	6.94 ± 0.10^{cB}	6.52 ± 0.13^{bC}	6.02 ± 0.13^{aB}
Flavour					
C	7.08 ± 0.15^{d}	6.95 ± 0.17^{c}	6.78 ± 0.15^{bA}	6.21 ± 0.14^{aA}	NP
PC	7.06 ± 0.07^{e}	6.91 ± 0.07^{d}	6.83 ± 0.07^{cAB}	6.51 ± 0.14^{bAB}	6.03 ± 0.19^{aA}
T	7.02 ± 0.06^{d}	6.89 ± 0.06^{c}	6.88 ± 0.07^{cB}	6.56 ± 0.11^{bB}	6.10 ± 0.13^{aB}
Juiciness					
C	7.18 ± 0.12^{b}	7.07 ± 0.13^{b}	6.88 ± 0.17^{bB}	6.19 ± 0.15^{aA}	NP
PC	7.15 ± 0.03^{b}	7.06 ± 0.06^{b}	6.73 ± 0.09^{cAB}	6.21 ± 0.18^{aA}	5.91 ± 0.20^{aA}
T	7.21 ± 0.05^{c}	7.10 ± 0.08^{c}	6.81 ± 0.09^{cA}	6.52 ± 0.15^{bB}	6.05 ± 0.18^{aB}
Tenderness					
C	7.12 ± 0.12^{cAB}	7.07 ± 0.12^{bcAB}	6.91 ± 0.11^{bB}	6.34 ± 0.14^{aA}	NP
PC	7.15 ± 0.07^{dAB}	$7.09\pm0.07cd^{AB}$	$6.89\pm0.07c^{AB}$	6.30 ± 0.09^{bA}	5.85 ± 0.11^{aA}
T	7.25 ± 0.09^{eB}	7.15 ± 0.06^{dB}	6.82 ± 0.07^{cA}	6.53 ± 0.12^{bB}	6.10 ± 0.057^{aB}
Overall acceptability					
C	7.25 ± 0.05^{dB}	7.01 ± 0.05^{c}	6.58 ± 0.06^{bA}	6.11 ± 0.11^{aA}	NP
PC	7.21 ± 0.09 dAB	7.03 ± 0.09^{c}	6.78 ± 0.02^{bBC}	6.28 ± 0.11^{aB}	5.85 ± 0.10^{aA}
T	7.19 ± 0.04^{dA}	7.05 ± 0.04^{c}	6.85 ± 0.02^{cC}	6.42 ± 0.17^{bC}	$6.110.05^{aB}$

Means with different superscripts differ significantly ($p < 0.05$) lowercase letters (a, b, c, ...) indicate differences within rows, while uppercase letters (A, B, C, ...) indicate differences within column; n = 6 for each treatment.

PRP- Papaya rind powder, JMS-jamun seed powder, Control- product without PRP and JMS, PC- product with 3% JMS, T- product with 3% JMS and 2% PRP

CONCLUSIONS

Thus, the incorporation of jamun seed powder and papaya rind powder improved the oxidative stability, as indicated by lipid oxidation parameters and microbial quality, of the restructured goat meat blocks under aerobic packaging conditions. The overall acceptability of the sample incorporated with JSP and PRP remains good to very good even after the 28 days of refrigerated storage under aerobic packaging.

COMPETING INTEREST

The authors do not have any competing interests among themselves or others related to this research work.

ETHICAL STATEMENT

Not applicable

REFERENCES

Ahmad, S. R., Sharma, B. D., Irshad, A., Kumar, R. R., Malav, O. P., & Talukder, S. (2021). Effect of aerobic storage on quality of functional restructured buffalo meat fillets enriched with dietary fibre and antioxidants. *Journal of Food Processing and Preservation, 45*(1), e15072.

Awad, A. M., Kumar, P., Ismail-Fitry, M. R., Jusoh, S., Ab Aziz, M. F., & Sazili, A. Q. (2021). Green extraction of bioactive compounds from plant biomass and applications in meat. *Antioxidants*, *10*(9), 1465. https://doi.org/10.3390/antiox10091465

Awad, A. M., Kumar, P., Ismail-Fitry, M. R., Jusoh, S., Ab Aziz, M. F., & Sazili, A. Q. (2022). Overview of plant extracts as natural preservatives in meat. *Journal of Food Processing and Preservation, 46*(8), e16796.

Balyan, U., & Sarkar, B. (2017). Aqueous extraction kinetics of phenolic compounds from jamun (*Syzygium cumini* L.) seeds. *International Journal of Food Properties, 20*(2), 372–389.

Bari, T., Saeed, S., Tayyab, M., Anjum, A. A., & Mehmood, T. (2024). GC–MS bioactives profiling, antibacterial and cytotoxic potential of jamun (*Syzygium cumini* L.) extracts against *Salmonella enteritidis*. *Pharmaceutical Chemistry Journal, 57*(10), 1586–1592.

Bhat, Z. F., Kumar, S., & Kumar, P. (2015). Effect of aloe vera on the lipid stability and storage quality of chicken nuggets. *Nutrition & Food Science, 45*(1), 54–67.

Gadekar, Y. P., Sharma, B. D., Shinde, A. K., Das, A. K., & Mendiratta, S. K. (2017). Effect of functional ingredients on low-fat restructured goat meat products. *Nutrition & Food Science, 47*(5), 731–740.

Gadekar, Y. P., Sharma, B. D., Shinde, A. K., & Mendiratta, S. K. (2015). Restructured meat products: Production, processing and marketing—A review. *Indian Journal of Small Ruminants, 21*(1), 1–12.

Gadekar, Y. P., Sharma, B. D., Shinde, A. K., Verma, A. K., & Mendiratta, S. K. (2014). Effect of natural antioxidants on quality of cured, restructured goat meat product during refrigerated storage. *Small Ruminant Research, 119*(3), 72–80.

Gupta, S., & Sharma, B. D. (2017). Effect of aerobic packaging on storage quality of functional restructured spent hen meat slices at refrigeration temperature. *Nutrition & Food Science, 47*(3).

Harzallah, A., Bhouri, A. M., Amri, Z., Soltana, H., & Hammami, M. (2016). Phytochemical content and antioxidant activity of different fruit parts juices of three figs (*Ficus carica* L.) varieties grown in Tunisia. *Industrial Crops and Products, 83*, 255–267.

Jamal, P., Akbar, I., Jaswir, I., & Zuhanis, Y. (2017). Quantification of total phenolic compounds in papaya fruit peel. *Pertanika Journal of Tropical Agricultural Science, 40*(1), 87–98.

Kantale, R. A., Kumar, P., Mehta, N., Chatli, M. K., Malav, O. P., Kaur, A., & Wagh, R. V. (2019). Comparative efficacy of synthetic and natural tenderizers on quality characteristics of restructured spent hen meat slices. *Food Science of Animal Resources, 39*(1), 121–138.

Keeton, J. T. (1983). Effect of fat and NaCl/phosphate levels on chemical and sensory properties of pork patties. *Journal of Food Science, 48*, 878–881.

Koniecko, E. S. (1979). *Handbook for meat chemists*. Avery Publishing Group.

Kumar, M., Zhang, B., Nishad, J., Verma, A., Sheri, V., Dhumal, S., & Radha. (2022). Jamun (*Syzygium cumini* (L.) Skeels) seed: Nutritional profile, functional food properties, health-promoting applications and safety aspects. *Processes, 10*(11), 2169.

Kumar, P., Abubakar, A. A., Ahmed, M. A., Hayat, M. N., Kaka, U., Pateiro, M., Sazili, A. Q., Hoffman, L. C., & Lorenzo, J. M. (2023). Pre-slaughter stress mitigation in goats: Prospects and challenges. *Meat Science, 195*, 109010.

Kumar, P., Ahmed, M. A., Hayat, M. N., Abubakar, A. A., Rahman, M. M., Ismail-Fitry, M. R., Kaka, U., & Sazili, A. Q. (2024). Ultrasound application and its effect on quality attributes of marinated goat meat. *Indian Journal of Small Ruminants, 30*(2), 293–298.

Kumar, P., Chatli, M. K., Mehta, N., Malav, O. P., Rathour, M., & Verma, A. K. (2018a). Antioxidant and antimicrobial efficacy of sapota powder in pork patties stored under different packaging conditions. *Korean Journal for Food Science of Animal Resources, 38*(3), 593–600.

Kumar, P., Mehta, N., Malav, O. P., Chatli, M. K., Rathour, M., & Verma, A. K. (2018b). Antioxidant and antimicrobial efficacy of watermelon rind extract in aerobically packaged pork patties stored under refrigeration. *Journal of Food Processing and Preservation, 42*, e13757.

Lohidas, J., Manjusha, S., & Glory Gnana Jothi, G. (2015). Antimicrobial activities of *Carica papaya* L. *Journal of Plant Sciences, 15*(2), 1179–1186.

Malav, O. P., Sharma, B. D., Talukder, S., Kumar, R. R., & Mendiratta, S. K. (2013). Shelf-life evaluation of restructured chicken meat blocks extended with sorghum flour and potato during refrigerated storage. *International Food Research Journal, 20*(1), 105–110.

Marina, Z., & Noriham, A. (2014). Quantification of total phenolic compounds and antioxidant potential of fruit peel extracts. *International Food Research Journal, 21*(5), 1925–1929.

Mireles-Arriaga, A. I., Ruiz-Nieto, J. E., Juárez-Abraham, M. R., Mendoza-Carrillo, M., & Martínez-Loperena, R. (2017). Functional restructured meat: Applications of plant-derived ingredients. *Vitae, 24*(3), 196–204.

Muhamad, S. A. S., Jamilah, B., Russly, A. R., & Faridah, A. (2017). In vitro antibacterial activities and composition of *Carica papaya* cv. Sekaki/Hong Kong peel extracts. *International Food Research Journal, 24*(3), 976–984.

Patel, P. R., & Rao, T. R. (2012). Antibacterial activity of underutilized fruits of jamun (*Syzygium cumini* L.). *International Journal of Current Pharmaceutical Research, 4*, 36–39.

Pathak, P. D., Mandavgane, S. A., & Kulkarni, B. D. (2019). Waste to wealth: A case study of papaya peel. *Waste and Biomass Valorization, 10*(6), 1755–1766.

Prasetya, A. T., Mursiti, S., Maryan, S., & Jati, N. K. (2018). Isolation and identification of active compounds from papaya plants and antimicrobial activity. *IOP Conference Series: Materials Science and Engineering, 349*, 012007.

Raja, W. H., Kumar, S., Bhat, Z. F., & Kumar, P. (2014). Effect of ambient storage on quality characteristics of aerobically packaged fish curls incorporated with different flours. *SpringerPlus, 3*, 106.

Reddy, G. B., Sen, A. R., Nair, P. N., Reddy, K. S., Reddy, K. K., & Kondaiah, N. (2013). Effects of grape seed extract on oxidative and microbial stability of restructured mutton slices. *Meat Science, 95*(2), 288–294.

Sharma, H., Sharma, B. D., Mendiratta, S. K., Talukder, S., &

Ramasamy, G. (2014). Efficacy of flaxseed flour as bind-enhancing agent in restructured mutton chops. *Asian-Australasian Journal of Animal Sciences, 27*(2), 247–254.

Sheard, P. (2002). Processing and quality control of restructured meat. In *Meat processing: Improving quality* (pp. 332–358).

Singh, P. K., Kumar, S., Kumar, P., Bhat, Z. F., & Kumar, A. (2015). Effect of processed oats and clove oil on characteristics and storage quality of aerobically packaged chevon cutlets. *Indian Journal of Small Ruminants, 21*(1), 76–84.

Singh, H., Kumar, P., Abhinandh, K., Sharma, A., Wagh, R. V., & Mehta, N. (2026). Development of restructured goat meat slices incorporated with jamun (*Syzygium cumini*) seed powder. *Indian Journal of Small Ruminants, 32*(1), 119–123.

Snedecor, G. W., & Cochran, W. G. (1989). *Statistical methods* (8th ed.). Iowa State University Press.

Sobri, R. A. M., Fuad, N. H. M., Halim, F. A., Kumar, P., Adewale, M. A., Rahman, M. M., Rashedi, I. F. M., & Sazili, A. Q. (2023). Effect of ultrasound and oil palm frond extract on quality characteristics of marinated goat meat. *Journal of Animal Research, 13*(1), 1–11.

Sudheer, K., Mandal, P. K., Das, C., Pal, U. K., Santoshkumar, H. T., & Rao, V. K. (2011). Development of restructured chicken block utilizing gizzard and its refrigerated storage stability. *Journal of Food Science and Technology, 48*(1), 96–101.

Tak, Y., Kaur, M., Jain, M. C., Samota, M. K., Meena, N. K., Kaur, G., Kumar, R., Sharma, D., Lorenzo, J. M., & Amarowicz, R. (2022). Jamun seed: Bioactive constituents, nutritional value and health benefits. *Polish Journal of Food and Nutrition Sciences, 72*(3), 211–228.

Talukder, S., Sharma, B. D., Mendiratta, S. K., Malav, O. P., Sharma, H., & Gokulakrishnan, P. (2013). Development and evaluation of extended restructured chicken meat block incorporated with colocasia flour. *Journal of Food Processing & Technology, 4*, 207.

Umaraw, P., Verma, A. K., & Kumar, P. (2017). Barbari goats: Current status. In *Sustainable goat production in adverse environments* (Vol. II, pp. 29–40). Springer.

Watkins, P. J., Jaborek, J. R., Teng, F., Day, L., Castada, H. Z., Baringer, S., & Wick, M. (2021). Branched-chain fatty acids in the flavour of sheep and goat milk and meat: A review. *Small Ruminant Research, 200*, 106398.

Witte, V. C., Krause, G. F., & Bailey, M. E. (1970). A new extraction method for determining thiobarbituric acid value of pork and beef during storage. *Journal of Food Science, 35*, 582–585.

How to Cite this Article: Harmanbir S., Kumar P., Wagh R.V., Singh C.. (2026). Storage Stability of Functional Restructured Goat Meat Blocks Stored in Aerobic Packaging under Refrigerated Conditions. *J. Meat Sci.*, ***21***(2), 22-29. https://doi.org/10.48165/jms.2026.21.02.04