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Effect of pomegranate rind extract on quality and storage stability of fermented carabeef jerky#

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Abstract

The study evaluated pomegranate rind extract (PRE) as a natural antioxidant in fermented carabeef jerky stored under aerobic packaging. Jerky was produced under optimised fermentation and drying conditions using a mixed starter culture, then formulated as C1 (no antioxidant), C2 (0.02% BHA:BHT, 1:1), and T1 (PRE 100 ppm). Pomegranate rind extract was characterised for pH, total phenolics, total flavonoids, gallic acid, and DPPH activity. Quality attributes, lipid oxidation (TBARS), microbiological profile, and sensory scores were monitored at 15 day intervals up to 75 days. The TBARS increased with storage in all treatments, but T1 consistently showed lower values, indicating reduced lipid oxidation. Group T1 also exhibited a smaller rise in pH and water activity and lower aerobic plate counts and yeast and mould growth during prolonged storage. Sensory scores declined with storage, while T1 maintained comparatively better flavour and overall acceptability. The findings indicate that PRE at 100 ppm can improve oxidative stability and storage quality of fermented carabeef jerky under aerobic packaging.

Keywords: Fermented carabeef jerky, pomegranate rind extract, natural antioxidant, aerobic packaging

Jerky is a shelf-stable dried meat product valued for its high protein content, convenience and extended keeping quality. However, quality deterioration during storage, particularly under aerobic packaging, remains a major concern due to lipid oxidation, protein degradation, colour changes and sensory decline. Fermentation has been widely adopted in meat processing to enhance microbial safety, flavour development and shelf stability through controlled acidification by lactic acid bacteria (LAB). In fermented jerky systems, appropriate control of fermentation and drying conditions is critical to ensure uniform acid development, desirable texture and acceptable sensory quality (Lücke, 1998; Luo et al., 2020).

Processing parameters and starter culture concentration play decisive roles in governing fermentation dynamics and product quality. Fermentation temperature, relative humidity and duration influence pH reduction, moisture removal and flavour formation, while starter culture level determines the rate and extent of lactic acid production. Moderate inoculation levels favour balanced acidification and sensory acceptability, whereas excessive starter concentrations may

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lead to over-acidification and reduced palatability. Earlier studies on fermented buffalo jerky have demonstrated that optimisation of fermentation conditions and starter culture concentration is essential for achieving desirable flavour, texture and product yield (Nairfana and Afgani, 2021; Toldrá, 2006).

Despite the benefits of fermentation, fermented meat products remain susceptible to oxidative deterioration during storage, especially under aerobic conditions. Increasing consumer demand for clean-label foods has encouraged the use of natural antioxidants to replace synthetic additives. Pomegranate rind extract is rich in phenolic compounds, flavonoids and gallic acid, exhibiting strong antioxidant and antimicrobial activities. Previous studies have shown that PRE effectively retards lipid oxidation, limits protein degradation and improves storage stability of meat products when incorporated at optimal levels, without adversely affecting sensory quality (Naveena et al., 2008). Therefore, the present study aimed to develop fermented carabeef jerky with optimised processing conditions and starter culture concentration and to evaluate the effect of PRE incorporation on quality attributes and storage stability under aerobic packaging.

Materials and methods

Preparation of fermented carabeef jerky

Fresh buffalo meat was procured and trimmed to remove visible fat, connective tissue and extraneous materials. The meat was cut into uniform chunks and sliced into strips (approximately 10 × 1 × 0.5 cm) using an automatic meat slicer (Model: 300 VV-CE) to ensure uniformity in size and drying behaviour. Ingredients were weighed as per the standard formulation, and the meat strips were transferred to a vacuum tumbler. Curing ingredients, spices and condiments were added in predetermined proportions, and the mixture was vacuum tumbled to ensure uniform distribution and to facilitate penetration of curing agents into the meat matrix. The optimised starter culture level (0.5%; mixed culture of *Pediococcus acidilactici* and *Lactobacillus plantarum*) was then incorporated, and vacuum tumbling was continued for a further 15 minutes.

Fermentation and drying were carried out under optimised processing conditions, namely fermentation at 25 °C and 95 – 98 per cent relative humidity for 24 h followed by drying at 15 °C and 85 – 90 per cent relative humidity for 48 h, as adapted from Luo et al. (2020).

Preparation of pomegranate rind extract

Pomegranate rind extract was prepared following the method of Kim et al. (2011) with minor modifications. Dried pomegranate rinds were dehydrated in a hot air dryer at 50 °C for 48 h until the moisture content reached approximately 4 per cent on a dry basis. The dried material (40 g) was then extracted with 400 mL of distilled water under reflux at 80 -100 °C for 3 h to obtain the first extract (Fraction I). The remaining residue was subjected to a second extraction using 600 mL of distilled water at 80 - 100 °C for 30 min to obtain Fraction II. Both extracts were cooled to room temperature and filtered through Whatman No. 1 filter paper. The filtrates were pooled and concentrated by drying in a hot air dryer at 50 °C for 6 - 8 h. The resulting dried extract was used for further analysis. Following the analysis of the phytochemical composition and antioxidant activity of pomegranate rind extract, the extract was incorporated into fermented carabeef jerky along with two controls: C1 (fermented carabeef jerky without any added antioxidant) and C2 (fermented carabeef jerky incorporated with a synthetic antioxidant at a level of 0.02 per cent using a 1:1 combination of BHA and BHT). A treatment (T1) was formulated by adding pomegranate rind extract at a level of 100 ppm.

Phytochemical composition and antioxidant activity of pomegranate rind extract (PRE)

The phytochemical characteristics and antioxidant activity of pomegranate rind extract were evaluated to determine its bioactive properties. The parameters analysed included pH, gallic acid content, total phenolic content, total flavonoid content, and antioxidant activity. Gallic acid content and total phenolic content were determined using the Folin–Ciocalteu method as described by Biswas et al. (2015) and Chandra et al. (2014), respectively. Total flavonoid content was estimated using the aluminium chloride colourimetric assay following the procedure of Marinova et al. (2005). The pH of the extract was measured using a digital pH meter. The antioxidant activity of the extract was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay according to the method described by Singh et al. (2002) with slight modifications. The mean (± SE) values of these parameters are presented in Table 1.

Cooking yield

The weight of jerky before and after cooking was recorded. Cooking yield was expressed as a percentage.

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked fermented jerky} \times 100}{\text{Weight of raw fermented jerky}}$$

The mean cooking yield values obtained for each treatment were statistically analysed, and the corresponding results are presented in Figure 1.

Proximate composition

Fermented carabeef jerky was assessed for proximate composition, *viz*., moisture content, protein and fat content. The proximate principles were expressed as percentages. The experiments were replicated six times.

Table 1. Mean (± SE) values of phytochemical characteristics and antioxidant activity of pomegranate rind extract (PRE)

Parameter	Mean ± SE
Gallic acid (mg/100 g)	8.26 ± 0.02
Total phenolics (mg GAE/100 g DM)	26.52 ± 0.45
Total flavonoids (mg QE/100 g DM)	12.42 ± 0.24
pH	3.13 ± 0.01
DPPH activity (%) – 50% concentration	92.28 ± 0.17
DPPH activity (%) – 100% concentration	96.34 ± 0.37

The results of the statistical analysis are presented in Table 2.

pH

The pH of the fermented carabeef jerky was determined using a digital pH meter (Latimer 2023). Ten grams of the sample were mixed with 50 mL of distilled water and homogenised. The pH was measured by using the combined electrode digital pH meter (μ pH system 362, Systronics, India). The results of the statistical analysis are presented in Table 3.

Water activity (a_w)

Water activity was carried out as per Carbonell et al. (2005) with the help of a water activity meter (Lab Swift, Novasina, Switzerland). The sample was placed in the sample container and then kept inside the sample chamber and the readings were taken when stable water activity was shown in the display. The results of the statistical analysis are presented in Table 4.

Thiobarbituric acid value

Thio-Barbituric Acid Reactive Substances (TBARS) value in fermented carabeef jerky samples was determined by the extraction method of Witte et al. (1970). TBARS estimation can be accomplished by measuring the concentration of secondary lipid oxidised products like malonaldehyde. Twenty grams of the sample was added with 50 mL of chilled extracting solution containing 20 per cent trichloroacetic acid (TCA) in two molar orthophosphoric acid and was homogenised for about 1.5 to 2 min. The resultant slurry was transferred to a 100 ml volumetric flask and made up to 100 mL with deionised distilled water, and this solution was filtered through Whatman No.1 filter paper. The filtrate was termed as TCA extract, and five millilitres of TCA extract was mixed with five millilitres of 2-thiobarbituric acid (TBA) solution (0.005 M in distilled water). Blank was constituted with five millilitres of distilled water and TBA solution. The constituted samples, along with blanks in tightly closed test tubes, were placed in a boiling water bath (100°C) for 30 min, and this was cooled for 10 min under cold running water. The developed colour was measured as absorbance value at 530 nm (Systronics-119, UV-visible spectrophotometer, Ahmadabad, India) and expressed as thiobarbituric acid number. TBARS value was expressed as mg malonaldehyde per kg of fermented carabeef jerky incorporated with antioxidant under aerobic packed in laminated pouches and studies were done on 0^{th}, 15^{th}, 30^{th}, 45^{th}, 60^{th} and 75^{th} day of storage study. The results of the statistical analysis are presented in Table 5.

Aerobic plate count

Total viable count of aerobic bacteria of each sample was estimated by the pour plate method, as described by Morton (2001) using Standard Plate Count Agar (HiMedia, Mumbai) and incubated at 37°C for 48 h, and the count was expressed as log10 CFU/g. The results of the statistical analysis are presented in Table 6.

Yeast and mould count

The method described by Beuchat and Cousin (2001) was followed for the estimation of yeast and mould count per gram of the sample. Sabouraud's Dextrose Agar (HiMedia, Mumbai) was used. The plates were incubated at 25-27°C for three days, and the count was expressed as log10 CFU/g. The results of the statistical analysis are presented in Table 7.

Sensory evaluation

Sensory evaluation of fermented carabeef jerky was carried out by a semi-trained panel consisting of seven

Table 2. Proximate composition of control and treatment fermented carabeef jerky (per cent wet basis of jerky (Mean ± SE) (n=6)

Parameter	C1	C2	T1	F value (p-value)
Moisture (%)	10.45 ± 0.88	10.88 ± 0.97	10.55 ± 0.94	0.048^{NS} (0.998)
Ash (%)	6.34 ± 0.16	6.19 ± 0.11	5.89 ± 0.13	2.169^{NS} (0.084)
Protein (%)	69.79 ± 0.99	69.96 ± 0.68	71.47 ± 0.91	0.996^{NS} (0.437)
Fat (%)	6.02 ± 0.04	6.03 ± 0.05	5.97 ± 0.07	0.643^{NS} (0.668)
NFE (%)	7.41 ± 1.05	6.94 ± 0.92	6.12 ± 0.88	0.699^{NS} (0.628)
Calorific value (kcal/kg)	3586 ± 27.30	3543 ± 23.7	3592 ± 29.0	0.421^{NS} (0.830)

Values are expressed as mean ± standard error (n = 6). Differences among treatments were not significant ($p > 0.05$). NS = non-significant

members from the Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Mannuthy, Thrissur. The samples were evaluated using an eight-point hedonic scale for sensory attributes including appearance, flavour, crispiness, saltiness, sourness, aftertaste and overall acceptability. Uniformly sized jerky samples, identified with random three-digit codes, were presented to the panelists for assessment. Plain water was provided between sample evaluations to cleanse the palate, and the average scores for each sensory attribute were calculated.

Results and discussion

Phytochemical composition and antioxidant activity of Pomegranate Rind Extract (PRE)

The phytochemical composition and antioxidant activity of pomegranate rind extract (PRE) are presented in Table 1. The extract contained gallic acid at 8.26 ± 0.02 mg/100 g. The total phenolic and total flavonoid contents were 26.52 ± 0.45 mg GAE/100 g dry matter and 12.42 ± 0.24 mg QE/100 g dry matter, respectively, indicating the presence of considerable amounts of bioactive phenolic compounds. The pH of the extract was 3.13 ± 0.01, reflecting its acidic nature. The antioxidant activity assessed by the DPPH radical scavenging assay showed high activity, with values of 92.28 ± 0.17% at 50 per cent concentration and 96.34 ± 0.37 per cent at 100 per cent concentration, indicating strong antioxidant potential of the extract.

Cooking yield

Product yield differed significantly in treatment T1 ($p < 0.01$) compared to C2 and C1 (Fig. 1), reflecting variations in moisture retention during processing and drying of fermented carabeef jerky. Treatment T1 recorded the highest yield (38.20± 0.51), followed by C2 (37.54 ± 0.46), while C1(36.79^{b} ± 0.44) exhibited the lowest yield, indicating greater moisture loss during processing. These differences can be attributed to variation in dehydration behaviour and solids retention among treatments. In general, dried meat products show reduced yields due to extensive moisture removal required to achieve low water activity and microbial stability, as dehydration-induced protein denaturation and muscle fibre contraction lead to structural shrinkage and water loss (Mediani et al., 2022).

Proximate composition

The proximate composition of fermented carabeef jerky did not differ significantly among treatments or packaging conditions ($p > 0.05$) (Table 2). Moisture, ash, protein, fat, nitrogen-free extract (NFE) and calorific value remained statistically comparable across all samples. Moisture content ranged from 10.45 to 10.90 per cent, protein from 69.79 to 71.95 per cent, fat from 5.95 to 6.07 per cent and ash from 5.87 to 6.34 per cent, with no significant differences observed for NFE or calorific value. These values are comparable with those reported for optimally fermented buffalo jerky prepared with 0.5 per cent LAB, which exhibited nutritionally acceptable moisture, protein, fat and ash contents (Nairfana and Afgani, 2021). Minor variations in absolute values may be attributed to differences in formulation and processing conditions; however, the results confirm that optimised fermentation and packaging do not markedly alter the proximate composition, thereby maintaining a stable nutritional profile.

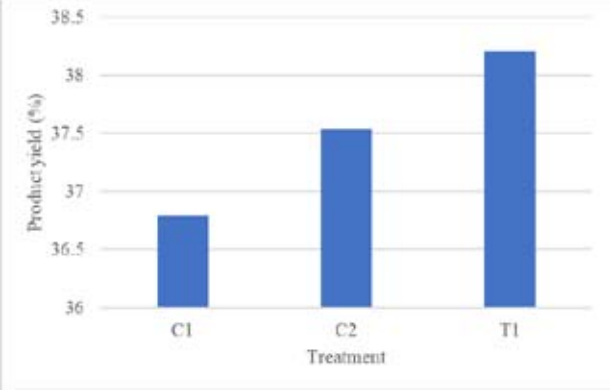

Fig. 1. Cooking yield on fermented carabeef jerky incorporated pomegranate rind extract (Mean ± SE) (n=6)

Table 3. Effect of Pomegranate rind extract on pH of fermented carabeef jerky

Sample	0th day	15th day	30th day	45th day	60th day	75th day	F value
C1	5.263^{aA} ± 0.010	5.277^{bA} ± 0.012	5.348^{cA} ± 0.010	5.430^{dA} ± 0.020	5.540^{eA} ± 0.024	5.640^{fA} ± 0.019	1193.834**
C2	5.260^{aA} ± 0.015	5.278^{bA} ± 0.008	5.312^{cB} ± 0.012	5.395^{dB} ± 0.012	5.477^{eB} ± 0.016	5.565^{fB} ± 0.008	763.014**
T1	5.260^{aA} ± 0.015	5.278^{bA} ± 0.008	5.297^{cB} ± 0.010	5.352^{dC} ± 0.012	5.410^{eC} ± 0.009	5.492^{fC} ± 0.012	418.955**
F value	0.781^{NS}	7.846**	58.511**	86.472**	148.538**	215.827**	

NS = non-significant ($p > 0.05$). ** Significant at 1 per cent level. Lowercase superscripts (a-f) denote row-wise comparison across storage days within the same sample, and mean values bearing different lowercase superscripts differ significantly ($p < 0.01$). Uppercase superscripts (A-D) denote column-wise comparison among treatments at the same storage day, and mean values bearing different uppercase superscripts differ significantly ($p < 0.01$). Values are expressed as mean ± standard error (n = 6). C1- Fermented carabeef jerky (control); C2 - Fermented carabeef jerky with synthetic antioxidant; T1 – Fermented carabeef jerky incorporated with PRE.

pH

The pH of fermented carabeef jerky increased significantly ($p < 0.01$) during storage under aerobic packaging in all treatments (Table 3). The pH of C1 increased from 5.263 to 5.640, C2 from 5.260 to 5.565, and T1 from 5.260 to 5.492 over the 75-day storage period. Among the treatments, T1 (100 ppm PRE) exhibited the least increase in pH, indicating a moderating effect of pomegranate rind extract on pH evolution. This moderated rise in pH may be attributed to the high phenolic content and antimicrobial activity of PRE, which can suppress spoilage-related biochemical changes during storage, as reported by Naveena et al. (2008).

Water activity

Water activity (a_w) of fermented carabeef jerky increased significantly ($p < 0.001$) during storage under aerobic packaging in all treatments (Table 4). The a_w values increased from 0.774 to 0.819 in C1, from 0.774 to 0.814 in C2, and from 0.775 to 0.809 in T1 over the 75-day storage period. Among the treatments, T1 (100 ppm PRE) exhibited a comparatively lower increase in a_v, indicating a moderating effect of pomegranate rind extract on moisture dynamics under aerobic packaging conditions.

Thiobarbituric acid (TBARS)

Thiobarbituric acid (TBARS) values of fermented carabeef jerky increased significantly with storage duration under aerobic packaging conditions ($p < 0.01$) (Table 5). Under aerobic packaging, TBARS values increased from 0.662 ± 0.014 to 1.904 ± 0.055 mg MDA/kg in C1, from 0.642 to 1.839 in C2, and from 0.662 to 1.738 in T1 over the 75-day storage period. Among the treatments, T1 (100 ppm PRE) consistently exhibited lower TBARS values, indicating reduced lipid oxidation. This suggests that incorporation of pomegranate rind extract effectively retarded oxidative deterioration due to its high phenolic content and antioxidant activity, in agreement with the findings of Naveena et al. (2008).

Aerobic Plate Count

Total viable count of fermented carabeef jerky increased significantly with storage duration under aerobic packaging conditions ($p < 0.01$) (Table 6). Under aerobic packaging, TVC increased from 4.01 to 6.88 log CFU/g in C1, from 3.84 to 6.72 log CFU/g in C2, and from 3.67 to 6.52 log CFU/g in T1 over the 75-day storage period. Among the treatments, T1 consistently exhibited lower microbial counts, indicating improved microbiological stability due to the incorporation of pomegranate rind extract. The reduced microbial growth in PRE-treated samples may be attributed to the antimicrobial activity of phenolic compounds, which suppress microbial proliferation during storage, thereby contributing to enhanced shelf stability. Kaderides et al. (2021) demonstrated that incorporation of pomegranate rind extracts in meat and other food systems enhanced microbiological stability and extended shelf life during storage, supporting the improved microbial stability observed in PRE-incorporated samples.

Table 4. Effect of Pomegranate rind extract on water activity of fermented carabeef jerky (Mean ± SE) (n=6)

Sample	0th day	15th day	30th day	45th day	60th day	75th day	F value
C1	$0.774^{aA} \pm 0.009$	$0.780^{bA} \pm 0.008$	$0.789^{cA} \pm 0.003$	$0.801^{dA} \pm 0.004$	$0.814^{eA} \pm 0.002$	$0.819^{eA} \pm 0.003$	64.421**
C2	$0.774^{aA} \pm 0.010$	$0.780^{bA} \pm 0.008$	$0.786^{cA} \pm 0.007$	$0.797^{dA} \pm 0.005$	$0.810^{eA} \pm 0.005$	$0.814^{eA} \pm 0.003$	52.360**
T1	$0.775^{aA} \pm 0.007$	$0.780^{bA} \pm 0.008$	$0.786^{cA} \pm 0.005$	$0.796^{dA} \pm 0.005$	$0.803^{eA} \pm 0.008$	$0.809^{eA} \pm 0.005$	36.536**
F value	0.02^{NS}	NS	0.643^{NS}	1.582^{NS}	5.214*	8.437**	

**Means bearing different superscripts (A–C between rows; a–f between columns) differ significantly (*P ≤ 0.05; P ≤ 0.01). NS – Non-significant (P > 0.05). Values are expressed as mean ± standard error (n = 6). C1 – Fermented carabeef jerky (control); C2 – Fermented carabeef jerky with synthetic antioxidant; T1 – Fermented carabeef jerky incorporated with PRE.

Table 5. Effect of Pomegranate rind extract on TBARS value of fermented carabeef jerky (Mean ± SE) (n=6)

Treatment	0th day	15th day	30th day	45th day	60th day	75th day	F value
C1	$0.662^{aA} \pm 0.014$	$1.0749^{bA} \pm 0.11$	$1.353^{cA} \pm 0.032$	$1.400^{dA} \pm 0.058$	$1.562^{eA} \pm 0.031$	$1.904^{fA} \pm 0.055$	183.891**
C2	$0.642^{aA} \pm 0.039$	$0.897^{bB} \pm 0.025$	$1.238^{cB} \pm 0.038$	$1.379^{dB} \pm 0.048$	$1.556^{eB} \pm 0.041$	$1.839^{fB} \pm 0.021$	198.935**
T1	$0.662^{aA} \pm 0.009$	$0.716^{bC} \pm 0.043$	$0.942^{cC} \pm 0.095$	$1.254^{dC} \pm 0.050$	$1.464^{eC} \pm 0.043$	$1.738^{fC} \pm 0.182$	196.790**
F value	1.090^{NS}	24.762**	51.293**	16.074**	8.987**	4.976*	

**Means bearing different superscripts (A–C between rows; a–f between columns) differs significantly (*P ≤ 0.05; P ≤ 0.01). NS – Non-significant (P > 0.05). Values are expressed as mean ± standard error (n = 6). C1 – Fermented carabeef jerky (control); C2 – Fermented carabeef jerky with synthetic antioxidant; T1 – Fermented carabeef jerky incorporated with PRE.

Yeast and Mould Count

Yeast and mould were not detected in any treatment up to the 30th day of storage, indicating good initial microbial stability of fermented carabeef jerky (Table 7). A significant increase in yeast and mould counts was observed from the 45th day onwards in all treatments ($p < 0.01$), reflecting the onset of fungal growth during prolonged storage. Under aerobic conditions, yeast and mould counts increased progressively, with C1 recording the highest values, followed by C2, while T1 (100 ppm pomegranate rind extract) consistently exhibited significantly lower counts throughout storage. The reduced fungal proliferation in T1 suggests an inhibitory effect of pomegranate rind extract, likely due to the antifungal activity of its phenolic compounds, thereby contributing to improved microbial stability during extended storage. Kaderides et al. (2021) reported that incorporation of pomegranate rind extracts in meat and other food systems significantly inhibited yeast and mould growth due to the antifungal activity of phenolic compounds, thereby enhancing microbiological stability and extending shelf life during storage.

Sensory evaluation

The sensory scores of fermented carabeef jerky during the 75 days of storage are presented in Table 8. Sensory attributes such as appearance, flavour, crispiness, saltiness, sourness, after taste and overall acceptability were comparable between treatments. All samples received high hedonic scores, indicating good initial sensory quality and consumer acceptability. The comparable scores suggest that incorporation of pomegranate rind extract at 100 ppm did not adversely affect the sensory characteristics of fermented carabeef jerky at the beginning of storage

Conclusion

Incorporation of pomegranate rind extract at 100 ppm effectively improved the quality and storage stability of fermented carabeef jerky under aerobic packaging. PRE enhanced product yield and helped maintain better stability during storage by moderating increases in pH and water activity, while significantly reducing lipid oxidation and protein degradation, as evidenced by lower TBARS values. The PRE-treated jerky also showed improved microbiological stability, with comparatively lower aerobic plate counts and reduced yeast and mould growth during prolonged storage. Overall, the results indicate that PRE can serve as a promising natural antioxidant for clean-label fermented jerky, improving sensory quality and oxidative stability during aerobic storage.

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Table 6. Effect of Pomegranate rind extract on Aerobic plate count value of fermented carabeef jerky (Mean ± SE) (n=6)

Treatment	0th day	15th day	30th day	45th day	60th day	75th day	F value
C1	$4.008^{aA} \pm 0.028$	$4.727^{bA} \pm 0.034$	$5.104^{cA} \pm 0.019$	$5.952^{dA} \pm 0.023$	$6.051^{eA} \pm 0.017$	$6.879^{fA} \pm 0.008$	3122.268**
C2	$3.837^{aB} \pm 0.042$	$4.583^{bB} \pm 0.008$	$4.906^{cB} \pm 0.012$	$5.725^{dB} \pm 0.023$	$5.912^{eB} \pm 0.020$	$6.723^{fB} \pm 0.021$	3226.972**
T1	$3.667^{aC} \pm 0.049$	$4.411^{bC} \pm 0.057$	$4.823^{cC} \pm 0.012$	$5.126^{dC} \pm 0.027$	$5.499^{eC} \pm 0.091$	$6.520^{fC} \pm 0.014$	3138.142**
F value	41.582**	76.914**	198.447**	312.685**	104.921**	210.364**	

**Means bearing different superscripts (A–C between rows; a–f between columns) differs significantly ($P \leq 0.01$). NS – Non-significant ($P > 0.05$). Values are expressed as mean ± standard error (n = 6). C1 – Fermented carabeef jerky (control); C2 – Fermented carabeef jerky with synthetic antioxidant; T1 – Fermented carabeef jerky incorporated with PRE.

Table7. Effect of Pomegranate rind extract on Yeast and Mould Count value of fermented carabeef jerky (Mean ± SE) (n=6)

Treatment	0th day	15th day	30th day	45th day	60th day	75th day	F value
C1	NIL	NIL	NIL	$1.039^{aA} \pm 0.353$	$1.791^{bA} \pm 0.117$	$2.562^{cA} \pm 0.137$	411.442**
C2	NIL	NIL	NIL	$0.895^{aA} \pm 0.353$	$1.705^{bA} \pm 0.117$	$2.198^{cB} \pm 0.137$	334.120**
T1	NIL	NIL	NIL	$0.602^{aA} \pm 0.353$	$1.301^{bB} \pm 0.117$	$1.898^{cC} \pm 0.137$	219.319**
F value	NIL	NIL	NIL	2.184^{NS}	9.742*	24.615**	

**Means bearing different superscripts (A–C between rows; a–c between columns) differs significantly (*$P \leq 0.05$; $P \leq 0.01$). NS – Non-significant ($P > 0.05$). Values are expressed as mean ± standard error (n = 6). NIL – Not detected. C1 – Fermented carabeef jerky (control); C2 – Fermented carabeef jerky with synthetic antioxidant; T1 – Fermented carabeef jerky incorporated with PRE.

Table 8. Effect of Pomegranate Rind Extract on sensory attributes of fermented carabeef jerky (Mean ± SE) (n=6)

	Storage days						
Sample	**0th day**	**15th day**	**30th day**	**45th day**	**60th day**	**75th day**	**F value**
	Appearance						
C1	$7.58^{aA} \pm 0.06$	$7.27^{bB} \pm 0.07$	$6.94^{cC} \pm 0.10$	$6.85^{dC} \pm 0.07$	$6.44^{eB} \pm 0.07$	$6.36^{fA} \pm 0.12$	412.86**
C2	$7.54^{aA} \pm 0.03$	$7.20^{bB} \pm 0.10$	$6.96^{cC} \pm 0.09$	$6.81^{dC} \pm 0.07$	$6.59^{eB} \pm 0.04$	$5.92^{fC} \pm 0.08$	398.42**
T1	$7.52^{aA} \pm 0.02$	$7.35^{bB} \pm 0.06$	$7.08^{cB} \pm 0.06$	$6.85^{dC} \pm 0.07$	$6.63^{eA} \pm 0.04$	$6.10^{fB} \pm 0.06$	356.77**
F value	0.52^{NS}	3.48^{NS}	6.92*	0.94^{NS}	5.86*	18.41**	
	Flavour						
C1	$7.31^{aA} \pm 0.21$	$7.27^{bA} \pm 0.20$	$6.88^{cB} \pm 0.28$	$6.73^{dB} \pm 0.17$	$6.42^{eB} \pm 0.23$	$6.21^{fB} \pm 0.45$	188.74**
C2	$7.46^{aA} \pm 0.21$	$7.20^{bA} \pm 0.30$	$6.96^{cB} \pm 0.09$	$6.76^{dB} \pm 0.20$	$6.53^{eB} \pm 0.17$	$5.88^{fC} \pm 0.25$	174.56**
T1	$7.63^{aA} \pm 0.12$	$7.35^{bA} \pm 0.17$	$6.98^{cB} \pm 0.06$	$6.80^{dB} \pm 0.20$	$6.56^{eB} \pm 0.15$	$6.06^{fB} \pm 0.22$	165.32**
F value	1.72^{NS}	0.84^{NS}	1.37^{NS}	0.63^{NS}	0.71^{NS}	5.94*	
	Crispiness						
C1	$7.39^{aA} \pm 0.16$	$7.06^{bB} \pm 0.08$	$6.65^{cB} \pm 0.14$	$6.42^{dA} \pm 0.23$	$6.25^{eB} \pm 0.25$	$5.81^{fB} \pm 0.26$	142.68**
C2	$7.35^{aA} \pm 0.26$	$7.07^{bB} \pm 0.28$	$6.70^{cB} \pm 0.18$	$6.50^{dA} \pm 0.22$	$6.25^{eB} \pm 0.24$	$5.71^{fC} \pm 0.21$	137.44**
T1	$7.42^{aA} \pm 0.13$	$7.23^{bA} \pm 0.22$	$6.92^{cA} \pm 0.70$	$6.55^{dA} \pm 0.20$	$6.20^{eC} \pm 0.24$	$5.60^{fC} \pm 0.28$	129.52**
F value	0.34^{NS}	4.21*	5.36*	0.91^{NS}	3.77*	7.94**	
	Saltiness						
C1	$7.58^{aA} \pm 0.06$	$7.27^{bB} \pm 0.07$	$6.94^{cB} \pm 0.10$	$6.85^{bB} \pm 0.07$	$6.44^{eB} \pm 0.07$	$6.36^{fB} \pm 0.12$	412.86**
C2	$7.54^{aA} \pm 0.03$	$7.20^{bB} \pm 0.10$	$6.96^{cB} \pm 0.09$	$6.81^{bB} \pm 0.07$	$6.59^{eB} \pm 0.04$	$5.92^{fC} \pm 0.08$	398.42**
T1	$7.52^{aA} \pm 0.02$	$7.35^{bB} \pm 0.06$	$7.08^{cA} \pm 0.06$	$6.85^{bB} \pm 0.07$	$6.63^{eA} \pm 0.04$	$6.10^{fB} \pm 0.06$	356.17**
F value	0.52^{NS}	3.48^{NS}	6.92*	0.94^{NS}	5.86*	18.41**	
	Sourness						
C1	$7.58^{aA} \pm 0.06$	$7.27^{bB} \pm 0.07$	$6.94^{cB} \pm 0.10$	$6.85^{bB} \pm 0.07$	$6.44^{eB} \pm 0.07$	$6.36^{fB} \pm 0.12$	412.86**
C2	$7.54^{aA} \pm 0.03$	$7.20^{bB} \pm 0.10$	$6.96^{cB} \pm 0.09$	$6.81^{bB} \pm 0.07$	$6.59^{eB} \pm 0.04$	$5.92^{fC} \pm 0.08$	398.42**
T1	$7.52^{aA} \pm 0.02$	$7.35^{bB} \pm 0.06$	$7.08^{cA} \pm 0.06$	$6.85^{bB} \pm 0.07$	$6.63^{eB} \pm 0.04$	$6.10^{fB} \pm 0.06$	356.17**
F value	0.52^{NS}	3.48^{NS}	6.92*	0.94^{NS}	0.81^{NS}	18.41**	
	After taste						
C1	$7.31^{aA} \pm 0.07$	$7.04^{dB} \pm 0.03$	$6.94^{cB} \pm 0.10$	$6.85^{dB} \pm 0.07$	$6.25^{eB} \pm 0.09$	$6.04^{fB} \pm 0.10$	276.18**
C2	$7.33^{aA} \pm 0.06$	$7.11^{dB} \pm 0.09$	$6.96^{cB} \pm 0.09$	$6.81^{dB} \pm 0.07$	$6.25^{eB} \pm 0.08$	$5.85^{fC} \pm 0.08$	268.54**
T1	$7.38^{aA} \pm 0.06$	$7.29^{bA} \pm 0.07$	$7.08^{cB} \pm 0.06$	$6.85^{dB} \pm 0.07$	$6.24^{eB} \pm 0.09$	$6.06^{fB} \pm 0.08$	241.36**
F value	0.41^{NS}	4.27*	2.83^{NS}	1.04^{NS}	0.21^{NS}	5.52*	
	Overall acceptability						
C1	$7.54^{aA} \pm 0.03$	$7.38^{bA} \pm 0.06$	$6.90^{cB} \pm 0.06$	$6.33^{dB} \pm 0.05$	$6.25^{eB} \pm 0.07$	$5.81^{fB} \pm 0.07$	
C2	$7.54^{aA} \pm 0.03$	$7.29^{bB} \pm 0.07$	$6.88^{cB} \pm 0.06$	$6.40^{dB} \pm 0.06$	$6.25^{eB} \pm 0.06$	$5.88^{fB} \pm 0.07$	
T1	$7.52^{aA} \pm 0.02$	$7.31^{bB} \pm 0.07$	$6.92^{cB} \pm 0.06$	$6.50^{dB} \pm 0.00$	$6.23^{eB} \pm 0.08$	$5.92^{fB} \pm 0.03$	
F value	0.19^{NS}	0.86^{NS}	1.21^{NS}	1.52^{NS}	0.14^{NS}	0.79^{NS}	

**Means bearing different superscripts (A–C between rows; a–f between columns) differs significantly (*P ≤ 0.05; P ≤ 0.01). NS – Non-significant (P > 0.05). Values are expressed as mean ± standard error (n = 6). NIL – Not detected. C1 – Fermented carabeef jerky (control); C2 – Fermented carabeef jerky with synthetic antioxidant; T1 – Fermented carabeef jerky incorporated with PRE.

Conflict of interest

The authors declared they have no conflict of interest

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