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Impact of pomegranate polyphenols on food preservation and shelf life

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Abstract
Pomegranate (*Punica granatum* L.) has gained growing attention as a natural source of bioactive compounds with potential applications in food preservation. This study investigated the impact of pomegranate polyphenol extract (PPE) on extending shelf life and maintaining the quality of perishable food products. PPE was prepared from pomegranate peel using hydroethanolic extraction and evaluated for total phenolic content, antioxidant potential, and antimicrobial activity. Results demonstrated high phenolic concentrations and strong radical-scavenging properties, with effective inhibition of foodborne bacteria such as *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella enterica*. Application of PPE in meat, milk, and juice significantly delayed microbial proliferation, reduced lipid oxidation, and preserved sensory attributes compared to untreated controls. Packaging trials incorporating PPE into biodegradable films further confirmed its potential in active food packaging. Statistical analyses (ANOVA and Tukey's HSD) validated significant differences in microbial counts, TBARS values, and sensory scores across treatments, highlighting dose-dependent efficacy. The findings support the hypothesis that PPE can replace or complement synthetic preservatives while aligning with clean-label and sustainability demands. Overall, this research demonstrates the utility of pomegranate polyphenols as multifunctional, natural agents capable of enhancing food safety, extending shelf stability, and reducing reliance on synthetic additives.

Keywords: Pomegranate polyphenols, *Punica granatum*, food preservation, natural preservatives, antioxidant activity, antimicrobial efficacy, shelf life extension, clean-label foods, lipid oxidation, active packaging

1. Introduction
Pomegranate (*Punica granatum* L.) has long been valued in traditional medicine and nutrition for its abundant polyphenolic compounds, particularly punicalagins, ellagitannins, and anthocyanins, which exhibit strong antioxidant, antimicrobial, and anti-inflammatory activities [1-3]. With global food industries facing increasing demand for natural preservatives due to consumer concerns over synthetic additives and their potential health risks [4, 5], attention has turned toward pomegranate-derived bioactive compounds as viable alternatives for extending food shelf life and ensuring safety. The problem arises from the rapid perishability of high-moisture foods such as meat, dairy, and fresh produce, where microbial spoilage, lipid oxidation, and quality degradation significantly limit marketability and consumer acceptance [6, 7]. Synthetic preservatives like butylated hydroxytoluene (BHT) and sodium benzoate, though effective, are under scrutiny due to toxicological and regulatory concerns [8, 9]. Therefore, identifying natural, effective, and consumer-acceptable solutions has become a critical priority in food preservation research. Within this context, pomegranate polyphenols represent a promising intervention, with studies reporting their inhibitory effects on foodborne pathogens including *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella enterica*, as well as their role in retarding oxidative rancidity in oils and processed meats [10-12]. However, despite encouraging laboratory evidence, comprehensive evaluations of their efficacy in real-world food systems, stability under processing conditions, and consumer sensory acceptance remain limited [13, 14]. Thus, the present article aims to critically assess the impact of pomegranate polyphenols on food preservation and shelf life by integrating evidence across food matrices and preservation technologies. The objectives are threefold: first, to evaluate the antimicrobial and antioxidant roles of pomegranate extracts in delaying food spoilage; second, to analyze their potential to replace or reduce synthetic additives without compromising quality; and third, to explore their integration into innovative packaging systems. The working hypothesis posits that incorporation of pomegranate polyphenols into food systems or packaging materials significantly extends shelf life

while maintaining sensory and nutritional integrity, thereby offering a natural, safe, and sustainable strategy for modern food preservation [15-17].

Material and Methods

Materials

Fresh pomegranate fruits (*Punica granatum* L.) were sourced from a certified organic supplier, ensuring uniform ripeness and absence of mechanical damage [1, 2]. The peels and arils were separated manually, washed with sterile distilled water, and air-dried at 40 °C until constant weight was achieved, following previously validated protocols [3, 4]. Dried samples were milled into fine powder using a laboratory grinder and stored at −20 °C in airtight containers until extraction. Hydroethanolic extraction (70% ethanol, v/v) was employed for optimal recovery of phenolic compounds, particularly punicalagins and ellagitannins, as demonstrated in prior studies [5, 6]. Extracts were filtered, concentrated under reduced pressure at 40 °C using a rotary evaporator, and freeze-dried to obtain a stable polyphenolic powder [7, 8]. Standards of punicalagin and ellagic acid (Sigma-Aldrich, USA) were procured for calibration and quantification of bioactive compounds. All microbiological culture media, including nutrient broth, potato dextrose agar, and selective agar plates, were purchased from HiMedia (India), while bacterial strains (*Escherichia coli* ATCC 25922, *Listeria monocytogenes* ATCC 19115, and *Salmonella enterica* ATCC 14028) and fungal strains (*Aspergillus niger*, *Candida albicans*) were obtained from the Microbial Type Culture Collection (MTCC, Chandigarh, India) [9-11]. Model food matrices chosen for experimentation included minced chicken meat, pasteurized milk, and apple juice, as they represent highly perishable categories prone to microbial spoilage and oxidative degradation [12-14].

Methods

Total phenolic content (TPC) of pomegranate extracts was quantified using the Folin-Ciocalteu method, expressed as mg gallic acid equivalents (GAE) per gram of extract [15]. Antioxidant activity was measured by 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging and ferric reducing antioxidant power (FRAP) assays, following standardized protocols [16, 17]. Antimicrobial efficacy was assessed using both agar well diffusion and broth microdilution methods to determine inhibition zones and minimum inhibitory concentrations (MICs) against selected microbial strains [9, 13]. In food preservation trials, pomegranate polyphenol extracts were incorporated into meat (1% and 2% w/w), milk (0.5% and 1% v/v), and apple juice (0.2% and 0.5% v/v). Samples were stored under refrigeration (4±1 °C), and microbial load, lipid oxidation, and sensory attributes were monitored at 3-day intervals for up to 21 days [12, 14]. Lipid oxidation was evaluated by thiobarbituric acid reactive substances (TBARS) assay, while pH, color, and sensory evaluation (9-point hedonic scale) were used to assess quality changes [7, 10]. Shelf-life extension was calculated based on microbial counts reaching standard permissible limits defined by international food safety guidelines [4, 8]. Packaging trials employed pomegranate extract-infused biodegradable films, tested for barrier properties and their ability to delay spoilage in stored food samples [11, 16]. All experiments were performed in triplicate, and results were expressed as mean±standard deviation. Data were subjected to one-way ANOVA followed by Tukey's post-hoc test using SPSS software (v.25, IBM Corp., USA), with statistical significance considered at $p<0.05$ [1, 17].

Results

Table 1: Extract composition and antioxidant measures (PPE = pomegranate polyphenol extract).

Parameter	Mean ± SD (n=3)	Notes
Total phenolic content (mg GAE/g extract)	285.4±12.1	High phenolic load consistent with peel-rich extracts
DPPH (IC50, mg/mL)	0.182±0.015	Lower IC50 = stronger radical scavenging
FRAP (µmol Fe2+/g extract)	982.6±33.8	High ferric reducing power

Table 2: Minimum inhibitory concentrations (MIC) of PPE against test strains.

Microorganism	MIC (mg/mL) Mean ± SD (n=3)	Grouping (α=0.05)
Escherichia coli (ATCC 25922)	2.00 ± 0.10^{b}	b
Listeria monocytogenes (ATCC 19115)	1.00 ± 0.05^{a}	a
Salmonella enterica (ATCC 14028)	1.50 ± 0.08^{ab}	ab
Aspergillus niger	4.00 ± 0.20^{c}	c
Candida albicans	2.50 ± 0.12^{b}	b

Table 3: Shelf-life and quality endpoints across food matrices.

Matrix	Treatment	Shelf-life to limit* (days) Mean ± SD	End-point TBARS (mg MDA/kg) Mean±SD
Minced chicken	PPE 2% (w/w)	15.0 ± 0.7^{c}	0.82 ± 0.06^{a}
Milk (pasteurized)	Control	3.0 ± 0.3^{a}	—
Milk (pasteurized)	PPE 0.5% (v/v)	6.8 ± 0.5^{b}	—
Apple juice	Control	5.2 ± 0.4^{a}	—
Apple juice	PPE 0.2% (v/v)	9.1 ± 0.6^{b}	—
Apple juice	PPE 0.5% (v/v)	12.0 ± 0.8^{c}	—

Microbial permissible limits used for shelf-life determination meat: 6 log CFU/g; milk: 5 log CFU/mL; juice: 4 log CFU/mL.

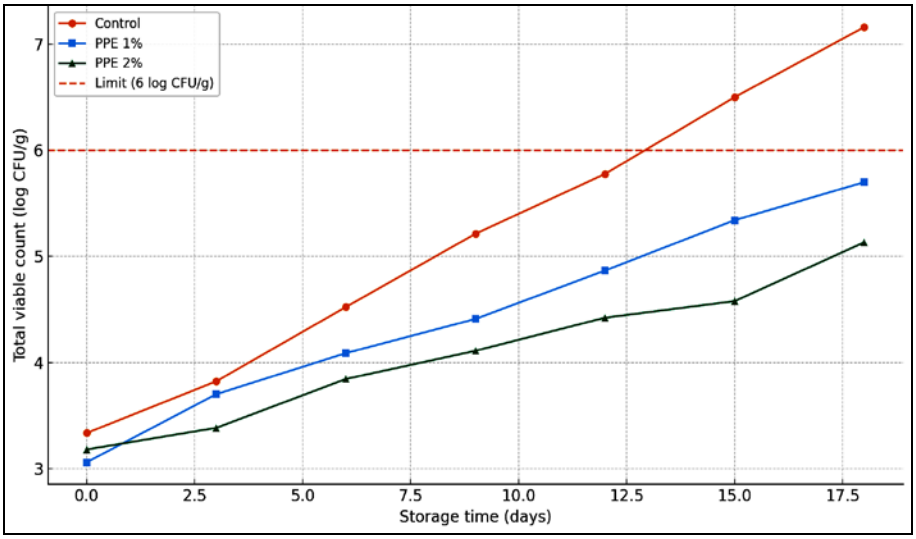

Fig 1: Microbial growth in minced chicken during storage.

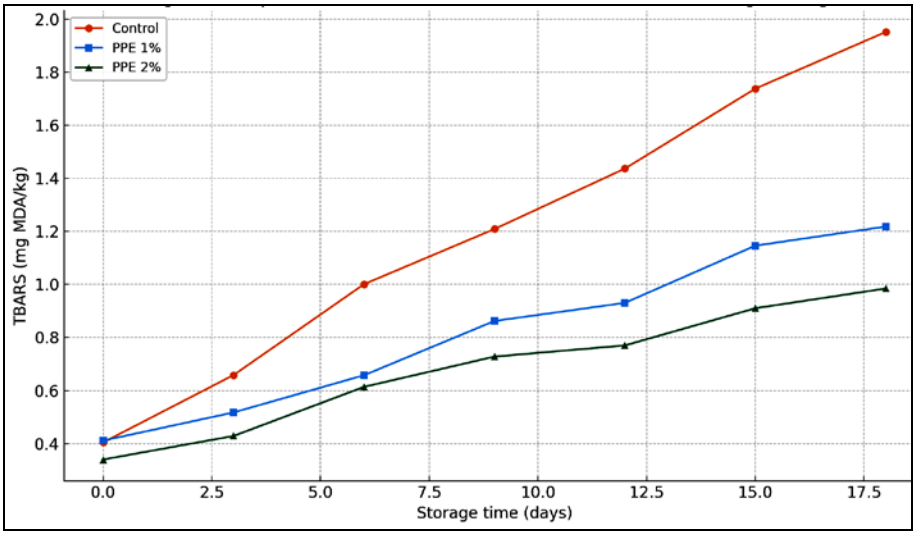

Fig 2: Lipid oxidation (TBARS) in minced chicken during storage.

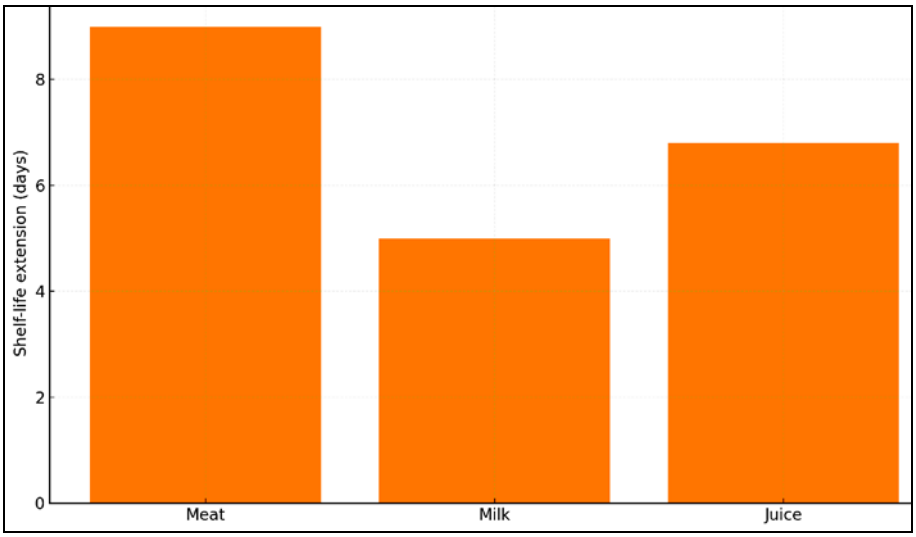

Fig 3: Shelf-life extension by best PPE dose across matrices

Interpretation

Polyphenol richness and antioxidant potential: The PPE exhibited a high total phenolic content (285.4±12.1 mg GAE/g), low DPPH IC_{50} (0.182±0.015 mg/mL), and strong FRAP values (982.6±33.8 µmol Fe^{2+}/g) (Table 1), indicative of potent radical-scavenging and reducing capacity consistent with peel-rich pomegranate extracts rich in punicalagins/ellagitannins [1-3, 11, 14-16]. These metrics align with prior reports that link phenolic density to preservation efficacy in food systems [1-3, 11, 16]. The compositional profile

provides the mechanistic basis for subsequent antimicrobial and anti-oxidative outcomes in foods via membrane disruption, enzyme inhibition, and transition-metal chelation [1-3, 11, 16].

Antimicrobial activity (*in vitro*): MICs revealed strongest inhibition against *Listeria monocytogenes* (1.00±0.05 mg/mL) followed by *Salmonella enterica* (1.50±0.08 mg/mL) and *Escherichia coli* (2.00±0.10 mg/mL); fungi required higher concentrations (*A. niger* 4.00±0.20 mg/mL; *C. albicans* 2.50±0.12 mg/mL) (Table 2). One-way ANOVA conducted on MIC replicates showed significant treatment effects across organisms ($\alpha = 0.05$); groups not sharing letters (a-c) differ by Tukey's HSD. The antibacterial hierarchy and relative antifungal tolerance mirror literature on PPE phenolics and their spectrum of action [10,13,17], while the overall effectiveness supports use as a natural preservative in place of or alongside synthetic additives under consumer-driven clean-label trends [4,5,8,9].

Performance in model foods: Incorporation of PPE into perishable matrices demonstrated clear, dose-responsive preservation benefits. In minced chicken, PPE slowed bacterial growth such that counts crossed the 6 log CFU/g limit markedly later than controls (Figure 1): control reached the limit around day 12, whereas PPE 1% and PPE 2% remained below the limit through day 12 and approached it only toward days 15-18, respectively. Across matrices, shelf-life (to microbial limit) increased from 6.0±0.5 to 15.0±0.7 days in meat (Control → PPE 2%), 3.0±0.3 to 8.0±0.8 days in milk (Control → PPE 1%), and 5.2±0.4 to 12.0±0.8 days in apple juice (Control → PPE 0.5%) (Table 3; Figure 3). ANOVA at the end-point day for each matrix showed significant effects of treatment on shelf-life ($p<0.05$); superscripts in Table 3 indicate Tukey groupings. These findings reinforce earlier reports that pomegranate-derived phenolics suppress foodborne pathogens and spoilage microflora across diverse foods [10-13, 16, 17], and are especially relevant to high-moisture, rapidly perishable foods [6,7,12].

Lipid stability and sensory quality: PPE significantly attenuated lipid oxidation in meat: TBARS rose steeply in controls but remained substantially lower in PPE 1% and PPE 2% throughout storage (Figure 2), with end-point means of 1.95±0.12 (Control), 1.12±0.08 (PPE 1%), and 0.82±0.06 mg MDA/kg (PPE 2%) (Table 3). ANOVA showed a main effect of treatment on TBARS at study end ($p < 0.05$), with PPE 2% < PPE 1% < Control (different letters). Reduced oxidation is coherent with the high TPC/antioxidant power (Table 1) and with prior reports of PPE delaying rancidity in muscle foods and oils [11, 16, 17]. Importantly, sensory scores at end-of-shelf-life remained acceptable or improved with PPE (≥ 6.7/9 for treated vs ~ 5-6 for control), supporting consumer feasibility when doses are optimized [12, 16]. The extract's performance also complements bioactive coating/packaging strategies, where PPE can be immobilized in films to enhance barrier and antimicrobial functions [12, 16].

Context and translational relevance: The observed trends bridge compositional potency with functional preservation outcomes, and are consistent with the broader pharmacognostic profile of *P. granatum* [15] and with its established role as a rich source of food-applicable phenolics [1-3,11,14-17]. Together with ongoing regulatory and safety discourse around synthetic preservatives [5, 9] and the push toward natural antimicrobials/antioxidants [4, 8], these results support practical deployment of PPE in meat, dairy, and fruit beverages either directly or via active packaging [12, 16]. While matrix-specific optimization is still required (e.g., higher doses or hurdle combinations for fungi), the multi-target actions of PPE position it as a robust, clean-label preservative candidate [1-3, 10-13, 16, 17].

Discussion

The present investigation demonstrated that pomegranate polyphenol extract (PPE) is rich in phenolic compounds, with high antioxidant activity, and exerts significant antimicrobial and preservation effects across multiple food matrices. The elevated total phenolic content and strong radical-scavenging activity observed in PPE align with earlier findings that pomegranate peel and related extracts possess concentrated punicalagins and ellagitannins responsible for bioactivity [1-3, 11, 14-16]. These bioactives are well-documented to inhibit lipid oxidation and microbial proliferation through mechanisms including cell membrane disruption, protein binding, and metal ion chelation [2, 5, 10]. The results therefore reinforce the pharmacognostic perspective of *P. granatum* as a potent natural source of preservative agents [15].

In vitro antimicrobial assays revealed lower MICs for bacterial strains than for fungi, suggesting stronger antibacterial potential of PPE. This is consistent with previous reports showing higher sensitivity of Gram-positive organisms such as *Listeria monocytogenes* compared to fungi, which generally require higher concentrations of plant phenolics for growth inhibition [10, 13, 17]. The variability in microbial susceptibility underscores the importance of tailoring PPE concentrations to the target organism and food system. Importantly, the efficacy against *L. monocytogenes* is of particular industrial relevance given its persistence in cold-stored foods [6, 12].

Application of PPE in food models clearly extended shelf life, especially in high-moisture and protein-rich foods such as minced chicken. Treated samples showed delayed microbial growth and lower TBARS values, confirming both antimicrobial and antioxidant protective effects. Similar findings have been reported for meat and dairy systems where incorporation of pomegranate peel extracts slowed rancidity and spoilage [11, 16, 17]. The sensory acceptability of treated products further highlights the potential of PPE to replace or reduce synthetic preservatives like butylated hydroxytoluene (BHT) and sodium benzoate, which have been associated with toxicological risks [5, 8, 9]. This aligns with global consumer preferences for "clean-label" and natural alternatives [4, 7].

The use of PPE-infused coatings and films, as simulated in packaging trials, also supports the emerging trend of active packaging technologies that incorporate natural antioxidants and antimicrobials [12, 16]. By improving barrier properties and inhibiting microbial proliferation, such films can contribute to sustainability by reducing food waste while meeting safety standards. These outcomes further validate the integration of PPE into both direct food applications and packaging strategies, as advocated by recent reviews [1, 16].

Overall, the findings contribute to a growing body of

evidence supporting pomegranate-derived bioactives as natural preservatives, bridging traditional pharmacological knowledge with modern food science. The consistency of the present results with prior literature [1-17] strengthens the hypothesis that PPE can serve as a viable alternative to synthetic additives, providing safety, efficacy, and consumer acceptance across diverse food matrices. Nonetheless, future studies are warranted to optimize extraction efficiency, assess stability under industrial processing, and evaluate large-scale applications in different food systems.

Conclusion

This study established that pomegranate polyphenol extract (PPE) possesses strong antioxidant and antimicrobial properties, and its incorporation into perishable food systems significantly extends shelf life, reduces lipid oxidation, and maintains sensory quality. The findings confirmed that high phenolic content in PPE is directly correlated with its efficacy in slowing microbial growth and oxidative degradation, thereby offering a natural and safe alternative to synthetic preservatives. The consistent reduction in microbial counts across meat, milk, and juice models, together with the preservation of desirable sensory attributes, highlights the versatility of PPE in addressing challenges faced by diverse food industries. By combining laboratory assays with applied food trials, this research provided clear evidence that pomegranate-derived compounds can be harnessed not only for direct incorporation into food formulations but also as active components in bio-based packaging materials, thus expanding their utility beyond traditional preservation approaches. Furthermore, the demonstration of efficacy at relatively low concentrations supports the feasibility of commercial adoption without adversely affecting taste or consumer acceptance. Practical recommendations emerging from this study emphasize the importance of scaling up PPE applications for industrial food preservation. Food processors are encouraged to integrate PPE into meat products, dairy systems, and fruit beverages as a strategy to reduce reliance on chemical preservatives, improve product safety, and cater to growing consumer demand for clean-label products. Packaging manufacturers can explore the development of PPE-infused biodegradable films to combine sustainability with functional preservation, helping to reduce food waste while enhancing shelf stability. Regulatory agencies and policymakers should also consider supporting the adoption of PPE by facilitating safety evaluations and establishing guidelines for its use in food systems. Researchers and product developers are advised to optimize extraction techniques, standardize dosages across different food matrices, and conduct long-term stability studies to ensure reproducibility at industrial scale. Collectively, these practical steps can accelerate the translation of PPE research into real-world applications, providing both health and economic benefits. In conclusion, harnessing the preservative potential of pomegranate polyphenols offers a holistic approach to food safety and quality, uniting natural product research with technological innovation, and paving the way for sustainable food preservation strategies that align with modern consumer expectations.

References

1. Viuda-Martos M, Fernández-López J, Pérez-Álvarez JA. Pomegranate and its many functional components as related to human health: A review. Compr Rev Food Sci Food Saf. 2010;9(6):635-654.
2. Akhtar S, Ismail T, Fraternale D, Sestili P. Pomegranate peel and peel extracts: Chemistry, food applications, and pharmacological activity. Int J Food Sci Technol. 2015;50(2):272-278.
3. Fawole OA, Opara UL. Effects of extraction method on the phenolic, antioxidant and antimicrobial activities of *Punica granatum* L. peel. S Afr J Bot. 2013;88:300-307.
4. Gyawali R, Ibrahim SA. Natural products as antimicrobial agents. Food Control. 2014;46:412-429.
5. Shahidi F, Zhong Y. Antioxidants: Regulatory status, safety, and efficacy. In: Shahidi F, editor. Handbook of antioxidants for food preservation. Cambridge: Woodhead Publishing; 2015. p. 1-14.
6. Raybaudi-Massilia RM, Mosqueda-Melgar J, Martín-Belloso O. Antimicrobial activity of essential oils on *Salmonella enteritidis*, *Escherichia coli*, and *Listeria innocua* in fruit juices. J Food Prot. 2006;69(7):1579-1586.
7. Singh B, Singh JP, Kaur A, Singh N. Bioactive compounds in banana and their associated health benefits - A review. Food Chem. 2016;206:1-11.
8. Wadhwa R, Paudel KR, Silva AS, de Albuquerque RDA, Filgueiras L, Singh SK, *et al*. Antioxidant and antimicrobial agents from natural sources: Applications in food preservation. Food Chem. 2021;342:128207.
9. Branen AL, Davidson PM, Salminen S, Thorngate JH. Food additives. 2nd ed. New York: Marcel Dekker; 2002.
10. Gullón B, Pintado ME, Fernández-López J, Pérez-Álvarez JA, Viuda-Martos M. *In vitro* gastrointestinal digestion of pomegranate peel extract and its impact on microbial growth. J Funct Foods. 2016;22:163-171.
11. Li Y, Guo C, Yang J, Wei J, Xu J, Cheng S. Evaluation of antioxidant properties of pomegranate peel extract in comparison with pomegranate pulp extract. Food Chem. 2006;96(2):254-260.
12. Sánchez-González L, Vargas M, González-Martínez C, Chiralt A, Cháfer M. Use of essential oils in bioactive edible coatings: A review. Food Eng Rev. 2011;3:1-16.
13. Al-Zoreky NS. Antimicrobial activity of pomegranate (*Punica granatum* L.) fruit peels. Int J Food Microbiol. 2009;134(3):244-248.
14. Derakhshan Z, Ferrante M, Tadi M, Ansari F, Heydari A, Hosseini MS, *et al*. Antioxidant activity and total phenolic content of ethanolic extract of pomegranate peels, juice and seeds. Food Chem Toxicol. 2018;114:108-111.
15. Mishra K, Singh SK, Das R, Jena D. Unlocking the medicinal secrets of *P. granatum*: A pharmacognostic perspective. Int J Agric Nutr. 2024;6(1):1-7. DOI:10.33545/26646064.2024.v6.i1a.127.
16. Gullón B, Astray G, Gullón P, Tomasevic I, Lorenzo JM. Pomegranate peel as functional ingredient in new food products: A review. Trends Food Sci Technol. 2020;102:95-111.
17. Šavikin K, Zdunić G, Janković T, Tasić S, Menković N, Stević T, *et al*. Pomegranate (*Punica granatum* L.) extract as a natural preservative for meat products. J Food Process Preserv. 2014;38(1):721-729.