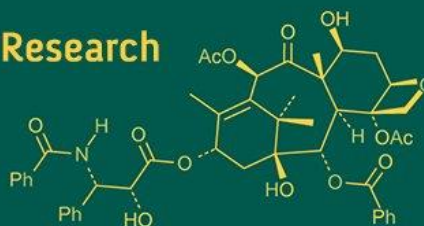


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(5): 1148-1153
www.biochemjournal.com
Received: 08-03-2026
Accepted: 12-04-2026

Nisha Dani
M.Sc. Research Scholar, FSN
Department, College of
Community & Applied
Sciences, MPUAT, Udaipur,
Rajasthan, India

Dr. Vishakha Singh
Associate Professor,
Department of Food Science
and Nutrition, College of
Community & Applied
Sciences, MPUAT, Udaipur,
Rajasthan, India

Dr. Sumitra Meena
Assistant Professor,
Department of Food Science
and Nutrition, College of
Community & Applied
Sciences, MPUAT, Udaipur,
Rajasthan, India

Dr. Rajshree Upadhyay
Professor, Department of
Extension Education and
Communication Management,
College of Community &
Applied Sciences, MPUAT,
Udaipur, Rajasthan, India

Dr. Rupal Babel
Associate Professor,
Department of Textiles and
Apparel Designing, College of
Community & Applied
Sciences, MPUAT, Udaipur,
Rajasthan, India

Corresponding Author:
Nisha Dani
M.Sc. Research Scholar, FSN
Department, College of
Community & Applied
Sciences, MPUAT, Udaipur,
Rajasthan, India

PhytoPack: Harnessing corn husk extract and rice paper sheet for the development and functional evaluation of plant-based antioxidant edible packaging

Nisha Dani, Vishakha Singh, Sumitra Meena, Rajshree Upadhyay and Rupal Babel

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i5Sm.8531>

Abstract

The escalating environmental burden associated with the extensive utilization of nonbiodegradable synthetic plastic packaging, coupled with increasing consumer demand for environmentally sustainable and health-promoting food preservation systems, has intensified scientific interest in the development of biodegradable and edible packaging materials derived from renewable biological resources. In this context, the present investigation was undertaken to develop and evaluate a plant-based antioxidant edible packaging material formulated from corn husk extract and rice paper sheet as an innovative and sustainable alternative to conventional synthetic packaging systems. Corn husk, an abundant yet underutilized agricultural by-product generated during maize processing, was selected owing to its rich composition of cellulose, lignocellulosic fibers, and naturally occurring phenolic compounds possessing significant antioxidant potential. Rice paper, recognized for its edibility, flexibility, film-forming capacity, and compatibility with food systems, was employed as the structural matrix for the development of the packaging material.

The formulation of the edible packaging sheets involved the aqueous extraction of bioactive constituents from dried corn husk followed by their incorporation into rice paper sheets to enhance the functional efficacy of the material. Natural plasticizers were incorporated during the development process to improve pliability, flexibility, and handling characteristics while maintaining the structural integrity of the sheets. The developed packaging material was subsequently subjected to functional evaluation with particular emphasis on antioxidant activity, which was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay to determine its free radical inhibition capacity and overall antioxidant effectiveness.

The findings of the study demonstrated that the developed edible packaging material exhibited substantial antioxidant activity ($72.00 \pm 2.00\%$), reflecting a pronounced free radical scavenging potential. The elevated antioxidant activity observed in the developed sheets may be primarily attributed to the successful incorporation and retention of phenolic compounds and other bioactive constituents inherently present in corn husk extract. These phytochemical compounds are recognized for their ability to neutralize reactive oxygen species and inhibit oxidative degradation processes, thereby contributing to the functional enhancement of food packaging systems. The incorporation of antioxidant-rich plant-derived materials into edible packaging offers an additional protective mechanism capable of minimizing oxidative deterioration, preserving nutritional quality, and potentially extending the shelf life of packaged food commodities.

Furthermore, the present study emphasizes the significance of agricultural waste valorization through the transformation of low-value by-products into high-value functional packaging materials, thereby contributing to sustainable resource utilization and circular economy principles. The utilization of corn husk as a renewable raw material not only addresses concerns related to agricultural waste accumulation but also promotes environmentally responsible approaches toward food packaging innovation. In addition, the relatively simple preparation methodology, minimal processing requirements, and dependence on locally available materials enhance the practical feasibility of the developed packaging sheets for adoption in small-scale industries, rural enterprises, and sustainable food production systems.

In conclusion, the developed corn husk extract-rice paper sheet demonstrated considerable potential as a plant-based antioxidant edible packaging material possessing desirable functional attributes and environmental compatibility. The study establishes a scientific foundation for the development of innovative, biodegradable, and antioxidant-enriched edible packaging systems capable of reducing dependence on synthetic plastics while simultaneously supporting food quality preservation and sustainable environmental practices.

Keywords: Corn husk extract, rice paper sheet, edible packaging material, antioxidant activity, DPPH radical scavenging assay, plant-based packaging, biodegradable food packaging, sustainable food systems, agricultural waste valorization

Introduction

The unprecedented increase in environmental pollution caused by the indiscriminate disposal and excessive utilization of synthetic plastic packaging materials has emerged as a major global concern, particularly within the food packaging sector.

Conventional petroleum-based plastics, although widely preferred due to their durability, low cost, and barrier properties, are inherently non-biodegradable and persist in the environment for prolonged periods, resulting in severe ecological consequences including soil contamination, water pollution, microplastic accumulation, and adverse impacts on terrestrial and aquatic ecosystems. The persistent nature of synthetic plastics has intensified concerns regarding environmental sustainability and has consequently accelerated the search for biodegradable, renewable, and environmentally benign alternatives capable of reducing ecological burden while ensuring food safety and quality.

In recent years, edible and biodegradable packaging materials have gained substantial scientific and industrial attention as promising substitutes for conventional food packaging systems. Edible packaging materials are thin layers of edible substances capable of serving as protective barriers around food products while simultaneously contributing functional and nutritional benefits. Unlike conventional packaging systems, edible films and coatings can either be consumed along with the food product or undergo natural biodegradation without causing environmental harm. Their inherent biodegradability, compatibility with food systems, and ability to act as carriers of bioactive compounds have positioned them as highly attractive solutions within sustainable food packaging technologies.

The growing emphasis on active food packaging has further stimulated research on the incorporation of naturally occurring functional compounds into packaging materials to enhance their protective efficacy. Among various active packaging approaches, antioxidant packaging has emerged as a particularly significant innovation due to its potential to retard oxidative degradation in food systems. Oxidative deterioration remains one of the principal causes of quality loss in food products, often resulting in lipid oxidation, discoloration, nutrient degradation, flavor deterioration, and reduced shelf stability. Therefore, the incorporation of natural antioxidants into edible packaging matrices has gained increasing importance as an effective strategy for minimizing oxidation-related quality deterioration while simultaneously improving the functional performance of packaging materials.

Agricultural by-products and agro-industrial residues have recently received considerable attention as sustainable raw materials for the development of biodegradable and functional packaging systems. The utilization of agricultural waste not only supports environmental sustainability but also contributes to waste valorization by transforming low-value residues into commercially valuable products. Corn husk, a major agricultural by-product generated during maize processing, represents one such underutilized lignocellulosic material possessing considerable functional potential. Despite being abundantly available in agricultural regions, corn husk is frequently discarded, burned, or utilized as low-value animal feed, thereby resulting in substantial biomass wastage. However, corn husk contains appreciable quantities of cellulose, hemicellulose, lignin, and phenolic compounds, making it a promising candidate for the development of biodegradable and functional food packaging materials.

Particularly noteworthy is the presence of bioactive phytochemicals and phenolic constituents in corn husk, which possess substantial antioxidant properties. Phenolic

compounds are recognized for their remarkable free radical scavenging capacity and their ability to inhibit oxidative reactions through hydrogen donation and electron transfer mechanisms. The incorporation of antioxidant-rich agricultural residues into edible packaging matrices may therefore enhance the functional efficacy of packaging systems by reducing oxidative stress and preserving the quality characteristics of food products. Such multifunctional packaging systems not only provide structural protection but also actively contribute to food preservation, thereby representing an advancement over passive packaging materials.

Rice paper has emerged as a highly suitable base material for the development of edible packaging systems owing to its edibility, biodegradability, flexibility, and excellent film-forming properties. Traditionally utilized in food applications, particularly in Asian culinary systems, rice paper possesses desirable mechanical characteristics and compatibility with various food ingredients, making it an effective matrix for the incorporation of functional additives. Its smooth texture, ease of handling, and ability to form thin and uniform sheets further enhance its suitability as a substrate for edible packaging development. The incorporation of corn husk extract into rice paper sheets may therefore provide an innovative approach toward the formulation of plant-based packaging materials possessing antioxidant functionality and enhanced sustainability.

The development of plant-based antioxidant edible packaging materials aligns closely with contemporary global priorities concerning sustainable development, circular economy principles, and environmentally responsible food systems. The utilization of biodegradable packaging derived from renewable biological resources offers significant opportunities for reducing dependency on petroleum-derived plastics while simultaneously addressing concerns related to agricultural waste management. Furthermore, the conversion of underutilized biomass into value-added packaging materials contributes to resource efficiency and supports environmentally sustainable production systems.

Despite increasing research interest in biodegradable and edible food packaging materials, limited scientific investigations have specifically explored the antioxidant potential of packaging systems developed using corn husk extract and rice paper sheet. Existing studies predominantly focus on starch-based films, protein-based edible coatings, or synthetic biodegradable polymers, with comparatively limited attention given to the functional incorporation of agricultural residues possessing inherent antioxidant properties. Therefore, there remains a substantial need for focused investigations aimed at evaluating the antioxidant functionality of edible packaging materials derived from naturally occurring agricultural by-products.

In view of these considerations, the present study was undertaken to develop and evaluate a plant-based antioxidant edible packaging material using corn husk extract and rice paper sheet. The investigation primarily focused on assessing the antioxidant potential of the developed packaging material through the DPPH radical scavenging assay in order to determine its functional suitability as an antioxidant-rich edible packaging system. By integrating agricultural waste valorization with sustainable packaging innovation, the study seeks to contribute toward the advancement of environmentally responsible food packaging technologies capable of

promoting both ecological sustainability and food quality preservation.

Methodology

The present investigation was undertaken to develop and evaluate a plant-based antioxidant edible packaging material using corn husk extract and rice paper sheet. The study was systematically designed to formulate an edible packaging material enriched with naturally occurring antioxidant compounds derived from corn husk and to evaluate its antioxidant potential through standardized analytical procedures. All experimental procedures were conducted under hygienic and controlled laboratory conditions to ensure consistency, reliability, and reproducibility of results.

Locale of the Study: The study was conducted in the laboratories of the Department of Food Science and Nutrition, College of Community and Applied Sciences, Udaipur. The department possesses adequate infrastructural facilities and laboratory equipment required for extraction, formulation, development, and functional evaluation of edible packaging materials. All experimental analyses were carried out under standardized laboratory conditions to maintain precision and minimize experimental variation.

Procurement and Preparation of Raw Materials: Corn husks were procured from local agricultural fields in and around Udaipur during the maize harvesting season. Fresh and healthy husks free from visible damage, fungal infestation, or contamination were selected for the study. The procured corn husks were thoroughly washed under running tap water followed by rinsing with distilled water to remove dirt, dust particles, and adhering impurities.

Following washing, the corn husks were dried under hygienic ambient conditions until complete removal of moisture was achieved. The dried material was subsequently cut into smaller pieces to facilitate efficient extraction of bioactive compounds. The prepared corn husk samples were stored in airtight containers at room temperature until further processing.

Rice paper sheets used as the edible structural matrix were procured from the local market. The sheets were stored in moisture-free conditions to preserve their texture, flexibility, and film-forming characteristics prior to use in packaging material development.

Preparation of Corn Husk Extract: The aqueous extraction method was employed for the preparation of corn husk extract. Dried corn husk pieces were weighed and boiled in distilled water for a predetermined duration to facilitate the extraction of bioactive constituents, particularly phenolic compounds possessing antioxidant potential. The extraction process allowed the release of soluble phytochemicals from the lignocellulosic matrix of the corn husk into the aqueous medium.

Following extraction, the solution was filtered using muslin cloth and filter paper to remove insoluble particles and obtain a clear extract. The prepared corn husk extract was allowed to cool to room temperature and subsequently utilized for the development of antioxidant edible packaging sheets.

Development of Plant-Based Antioxidant Edible Packaging Material: The development of edible packaging

sheets was carried out using rice paper as the base matrix and corn husk extract as the functional antioxidant component. Rice paper sheets were initially conditioned by slight moistening to improve flexibility and facilitate uniform coating.

The prepared corn husk extract was uniformly applied onto the surface of rice paper sheets to ensure even distribution of antioxidant compounds. To improve flexibility, reduce brittleness, and enhance handling characteristics, natural plasticizers such as glycerol or starch solution were incorporated in optimized quantities during formulation.

The coated sheets were subsequently dried under controlled ambient conditions to remove excess moisture and ensure proper adhesion of the extract onto the rice paper matrix. Several preliminary standardization trials were performed to achieve uniformity in coating, appearance, flexibility, and overall sheet quality. The developed sheets were carefully stored in airtight containers until further antioxidant evaluation.

Evaluation of Antioxidant Activity: The antioxidant potential of the developed edible packaging material was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay, a widely accepted and reliable analytical method for determining free radical scavenging activity in plant-derived materials.

The developed packaging sheet samples were prepared for extraction, and their antioxidant activity was determined based on the ability of bioactive compounds to neutralize DPPH free radicals. The reduction in absorbance was measured spectrophotometrically at an appropriate wavelength, and the percentage inhibition of free radicals was calculated to determine antioxidant capacity.

The antioxidant activity was expressed as percentage radical scavenging activity using the following formula:

% Antioxidant Activity = $A_0 - A_1 / A_0 \times 100$ Where:

A_0 = Absorbance of control (DPPH solution without sample)

A_1 = Absorbance of sample (DPPH solution with corn husk extract)

Higher percentage inhibition indicated greater antioxidant activity and stronger free radical scavenging potential of the developed packaging material.

Statistical Analysis: All experimental analyses were carried out in triplicates to ensure accuracy, reliability, and reproducibility of the findings. The data obtained were statistically analyzed, and results were expressed as Mean $\pm$ Standard Deviation (SD). Descriptive statistical methods were used to interpret the antioxidant activity of the developed packaging sheets and to assess consistency among observations.

Results

Antioxidant Activity of Developed Edible Packaging Material

Table 1: Antioxidant Activity of Plant-Based Edible Packaging Material Developed from Corn Husk Extract and Rice Paper Sheet

Parameter	Mean $\pm$ SD
Antioxidant Activity (%)	72.00 $\pm$ 2.00

The functional evaluation of the developed plant-based edible packaging material revealed substantial antioxidant activity, indicating the successful incorporation of bioactive compounds derived from corn husk extract into the rice paper matrix. The antioxidant potential of the developed sheets was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay, which demonstrated an antioxidant activity of $72.00 \pm 2.00\%$, reflecting a pronounced capacity to neutralize free radicals.

The relatively high antioxidant activity observed in the developed packaging material may be primarily attributed to the presence of naturally occurring phenolic compounds and phytochemicals present in corn husk extract. Corn husk, although frequently regarded as an agricultural residue, possesses considerable concentrations of lignocellulosic components and polyphenolic substances capable of exerting significant antioxidant effects. These bioactive constituents function by donating hydrogen atoms or electrons to unstable free radicals, thereby inhibiting oxidative reactions and reducing oxidative stress. The findings therefore indicate that the extraction and incorporation process effectively retained the antioxidant constituents of corn husk within the edible packaging matrix.

The observed antioxidant potential further demonstrates the functional suitability of rice paper as an effective carrier material for plant-derived antioxidant compounds. Rice paper, due to its porous structure and film-forming ability, likely facilitated the efficient adsorption and retention of bioactive substances from corn husk extract. This compatibility between rice paper and plant extract contributed to the development of a stable edible sheet with enhanced functional characteristics. Furthermore, the incorporation of natural plasticizers during formulation may have improved the uniform distribution of antioxidant compounds throughout the packaging matrix, thereby contributing to consistent antioxidant performance.

The substantial radical scavenging activity exhibited by the developed edible packaging material suggests its potential utility as an active food packaging system. Oxidative deterioration is widely recognized as one of the major causes of quality degradation in food products, particularly in lipid-rich foods where oxidation contributes to rancidity, undesirable flavor changes, nutrient degradation, discoloration, and reduced shelf stability. The incorporation of antioxidant-rich edible packaging materials may therefore provide an additional protective mechanism capable of minimizing oxidative spoilage and preserving food quality during storage.

The antioxidant efficacy demonstrated in the present investigation highlights the growing importance of integrating naturally occurring plant bioactives into sustainable food packaging systems. Unlike conventional synthetic packaging materials, which primarily serve passive protective functions, antioxidant edible packaging actively contributes to food preservation by limiting oxidative damage. Consequently, the developed corn husk extract-rice paper sheet may serve as a multifunctional packaging material capable of simultaneously providing structural protection and antioxidant functionality.

The low standard deviation (± 2.00) associated with antioxidant activity indicates good uniformity and reproducibility in sheet development and analytical procedures. This consistency suggests that the methodology

employed for extraction, coating, and sheet preparation was effective in producing a relatively homogeneous distribution of antioxidant compounds across the developed packaging material. Such reproducibility is essential for ensuring reliability and practical applicability in potential large-scale production systems.

Overall Interpretation of Results

The findings of the present investigation clearly establish that the developed plant-based edible packaging material formulated from corn husk extract and rice paper sheet possesses considerable antioxidant potential and functional suitability for sustainable food packaging applications. The substantial antioxidant activity observed in the developed sheets confirms the successful utilization of corn husk as a valuable source of natural bioactive compounds capable of enhancing the functional efficacy of edible packaging systems.

The incorporation of corn husk extract into rice paper significantly contributed to the development of an antioxidant-enriched packaging material capable of scavenging free radicals and potentially minimizing oxidative deterioration in food products. This functional property represents a substantial advancement over conventional packaging materials by introducing an active preservation mechanism into the packaging system. The ability of the developed sheets to exhibit strong antioxidant activity suggests their possible role in maintaining food freshness, preserving nutritional quality, and delaying oxidative spoilage.

From an environmental perspective, the study further emphasizes the significance of agricultural waste valorization through the transformation of underutilized biomass into high-value functional products. The utilization of corn husk, an abundantly available agricultural by-product, not only contributes to waste minimization but also supports sustainable resource utilization and circular economy principles. The conversion of agricultural residues into biodegradable edible packaging materials offers a promising strategy for reducing environmental pollution associated with synthetic plastic waste.

Moreover, the relatively simple preparation methodology and reliance on locally available raw materials increase the practical feasibility and economic viability of the developed packaging system, particularly for small-scale food industries, cottage enterprises, and rural entrepreneurial initiatives. The integration of plant-derived antioxidant compounds into edible packaging systems may therefore contribute significantly toward the development of environmentally sustainable, functionally enhanced, and consumer-friendly food packaging technologies.

Overall, the present investigation demonstrates that corn husk extract-incorporated rice paper sheets possess promising antioxidant functionality and considerable potential as plant-based edible packaging materials. Nevertheless, further research concerning mechanical properties, storage stability, barrier characteristics, and application-specific performance may be undertaken to improve their commercial applicability and expand their utilization across diverse food packaging systems.

Conclusion

The present investigation conclusively establishes the technical feasibility and functional efficacy of developing a

plant-based antioxidant edible packaging material utilizing corn husk extract and rice paper sheet as sustainable alternatives to conventional petroleum-derived food packaging systems. By strategically integrating an underutilized agricultural by-product with an edible filmforming substrate, the study successfully demonstrated an innovative approach toward the development of environmentally sustainable, functionally enhanced, and biologically active food packaging materials. The findings reinforce the growing scientific consensus advocating the transition from synthetic, non-biodegradable packaging systems toward renewable, biodegradable, and eco-compatible alternatives capable of addressing contemporary environmental and food preservation challenges.

The successful incorporation of corn husk extract into the rice paper matrix substantially contributed to the functional enhancement of the developed packaging material, particularly with respect to antioxidant efficacy. The pronounced antioxidant activity observed through the DPPH radical scavenging assay confirms the effective retention and bioavailability of naturally occurring phenolic compounds and phytochemical constituents inherently present in corn husk. These bioactive compounds are recognized for their ability to neutralize reactive oxygen species, suppress oxidative chain reactions, and mitigate oxidative degradation processes responsible for quality deterioration in food products. Consequently, the developed edible packaging material demonstrates considerable potential to function not merely as a passive protective barrier but as an active antioxidant packaging system capable of contributing directly to food preservation and quality maintenance.

The elevated antioxidant potential exhibited by the developed sheets signifies important implications for the food packaging sector, particularly in the context of extending product shelf stability and preserving physicochemical and sensory attributes of food commodities. Oxidative degradation remains one of the principal determinants of quality loss in packaged food systems, often resulting in lipid peroxidation, nutrient depletion, discoloration, flavor deterioration, and reduced consumer acceptability. The incorporation of antioxidant-rich plant-derived extracts into edible packaging materials therefore represents a scientifically promising and commercially relevant strategy for minimizing oxidation-induced spoilage while simultaneously improving food safety and product quality.

Moreover, the present study substantially contributes to the concept of agricultural waste valorization, emphasizing the transformative potential of converting low-value agro-residues into value-added functional materials. Corn husk, frequently regarded as an agricultural waste product with limited economic significance, was effectively utilized as a renewable source of antioxidant compounds, thereby promoting sustainable biomass utilization and minimizing environmental waste accumulation. Such an approach aligns strongly with the principles of circular bioeconomy and sustainable resource management, wherein agricultural residues are repurposed into commercially valuable products with enhanced functional applications.

The selection of rice paper as the edible structural matrix further strengthened the practical applicability of the developed packaging system due to its favorable characteristics including edibility, flexibility, film-forming

capability, and compatibility with food-grade materials. Additionally, the relatively uncomplicated preparation methodology, minimal technological requirements, and reliance on locally available raw materials significantly enhance the scalability and economic feasibility of the developed packaging material for implementation within small-scale industries, cottage enterprises, and decentralized rural production systems. This may further facilitate entrepreneurship, income generation, and sustainable industrial development in agricultural communities.

From a broader sustainability perspective, the outcomes of the present investigation underscore the critical importance of developing multifunctional packaging systems capable of simultaneously addressing environmental sustainability, food quality preservation, and agricultural waste management. The developed antioxidant edible packaging material offers a compelling alternative to synthetic plastics by integrating functional bioactivity, environmental compatibility, and resource sustainability within a single packaging platform.

In conclusion, the corn husk extract-incorporated rice paper sheet developed in the present study demonstrates substantial promise as a novel plant-based antioxidant edible packaging material possessing considerable functional and environmental significance. Nevertheless, future investigations focusing on optimization of extraction efficiency, enhancement of physicochemical and barrier properties, incorporation of complementary bioactive agents, storage performance under diverse environmental conditions, and real-food application studies are strongly recommended to further strengthen commercial viability and industrial applicability. The advancement of such innovative edible packaging technologies may play a transformative role in shaping the future of sustainable food packaging systems and promoting environmentally resilient food supply chains.

References

1. Ahmad M, Benjakul S, Prodpran T, Agustini TW. Physico-mechanical and antimicrobial properties of gelatin film from the skin of unicorn leatherjacket incorporated with essential oils. *Food Hydrocoll.* 2012;28(1):189-199.
2. Atarés L, Chiralt A. Essential oils as additives in biodegradable films and coatings for active food packaging. *Trends Food Sci Technol.* 2016;48:51-62.
3. Azeredo HMC, Otoni CG, Mattoso LHC. Edible films and coatings—Not just packaging materials. *Curr Res Food Sci.* 2022;5:1590-1595.
4. Bertuzzi MA, Vidaurre EC, Armada M, Gottifredi JC. Water vapor permeability of edible starch-based films. *J Food Eng.* 2007;80(3):972-978.
5. Chen W, Ma S, Wang Q, McClements DJ, Liu X, Ngai T, *et al.* Fortification of edible films with bioactive agents: A review of their formation, properties, and application in food preservation. *Crit Rev Food Sci Nutr.* 2022;62(18):5029-5055.
6. Elsabee MZ, Abdou ES. Chitosan-based edible films and coatings: A review. *Mater Sci Eng C.* 2013;33(4):1819-1841.
7. Espitia PJP, Du WX, Avena-Bustillos RJ, Soares NFF, McHugh TH. Edible films and coatings from pectin: Physical-mechanical and antimicrobial properties. *Food Hydrocoll.* 2014;35:287-296.

8. Falguera V, Quintero JP, Jiménez A, Muñoz JA, Ibarz A. Edible films and coatings: Structures, active functions and trends in their use. *Trends Food Sci Technol.* 2011;22(6):292-303.
9. Galus S, Kadzińska J. Food applications of emulsion-based edible films and coatings. *Trends Food Sci Technol.* 2015;45(2):273-283.
10. Guilbert S, Gontard N, Gorris LGM. Prolongation of the shelf-life of perishable food products using biodegradable films and coatings. *LWT Food Sci Technol.* 1996;29(1-2):10-17.
11. Han JH. Antimicrobial food packaging. *Food Technol.* 2000;54(3):56-65.
12. Janjarasskul T, Krochta JM. Edible packaging materials. *Annu Rev Food Sci Technol.* 2010;1(1):415-448.
13. Jeevahan J, Chandrasekaran M. Nanoedible films for food packaging: A review. *J Mater Sci.* 2019;54:12290-12318.
14. Kester JJ, Fennema OR. Edible films and coatings: A review. *Food Technol.* 1986;40(12):47-59.
15. Krochta JM, De Mulder-Johnston C. Edible and biodegradable polymer films: Challenges and opportunities. *Food Technol.* 1997;51(2):61-74.
16. Kumar L, Ramakanth D, Akhila K, Gaikwad KK. Edible films and coatings for food packaging applications: A review. *Environ Chem Lett.* 2022;20(2):875-900.
17. McHugh TH, Aujard JF, Krochta JM. Plasticized whey protein edible films: Water vapor permeability properties. *J Food Sci.* 1994;59(2):416-419.
18. Mohamed SAA, El-Sakhawy M, El-Sakhawy MAM. Polysaccharides, protein and lipid-based natural edible films in food packaging: A review. *Carbohydr Polym.* 2020;238:116178.
19. Morillon V, Debeaufort F, Blond G, Capelle M, Voilley A. Factors affecting the moisture permeability of lipid-based edible films. *Crit Rev Food Sci Nutr.* 2002;42(1):67-89.
20. Rojas-Graü MA, Soliva-Fortuny R, Martín-Belloso O. Edible coatings to incorporate active ingredients to fresh-cut fruits: A review. *Trends Food Sci Technol.* 2009;20(10):438-447.
21. Sahraee S, Milani JM, Regenstein JM, Kafil HS. Protection of foods against oxidative deterioration using edible films and coatings: A review. *Food Biosci.* 2019;32:100451.
22. Siracusa V, Rocculi P, Romani S, Dalla Rosa M. Biodegradable polymers for food packaging: A review. *Trends Food Sci Technol.* 2008;19(12):634-643.
23. Sothornvit R, Krochta JM. Plasticizers in edible films and coatings. *Innov Food Sci Emerg Technol.* 2000;1(2):107-117.
24. Valdés A, Ramos M, Beltrán A, Jiménez A, Garrigós MC. State of the art of antimicrobial edible coatings for food packaging applications. *Coatings.* 2015;5(4):771-791.