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Article

Extending the Shelf Life of French Fries with Edible Bioactive Coatings from Potato Peels

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Abstract: This study explored the potential of potato peel-derived edible coatings to extend the shelf life of French fries. Potato peels, a food industry byproduct, were utilized as a sustainable source of bioactive compounds. The dried peel composition was analyzed, and an ethanolic extract was prepared. Edible coatings were formulated using this extract, glycerol as a plasticizer, and water as a solvent. French fry samples were coated and stored at 4°C and 50% relative humidity for 18 hours. Peroxide values were monitored during a 9-day refrigerated storage period. Results showed that coated samples had lower peroxide values (13.7 meq/1000g) compared to uncoated controls (17.5 meq/1000g), suggesting the coatings effectively delayed oxidative deterioration. This study demonstrates the potential of potato peel-derived coatings in extending the shelf life of fried food products.

Keywords: Potato Peels, Bioactive Compounds, Antioxidant, Ultrasound Treatment Waste Food Management.

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1. Introduction

Food preservation is a critical component of the food supply chain, ensuring that food remains safe, nutritious, and palatable for consumption over extended periods. The main goals of food preservation are to prevent spoilage, minimize food waste, and retain the quality and safety of food products (Chauhan, Dhir et al. 2021) . As global populations rise and urbanization increases, the demand for effective food preservation methods has become more pressing, highlighting the need for innovative solutions that adapt to changing consumer preferences and technological advancements.

Food preservation plays several key roles. First and foremost, it enhances safety by inhibiting the growth of pathogenic bacteria, yeast, and Molds that can lead to foodborne illnesses (Fuenmayor and Licciardello 2024). Effective preservation methods not only reduce health risks but also ensure that the nutritional quality of food is maintained. By slowing down enzymatic degradation and oxidation processes, techniques such as refrigeration or the use of preservatives help retain essential vitamins and minerals (Olvera-Aguirre, Piñeiro-Vázquez et al. 2023). Additionally, effective preservation is economically significant; the global food system faces substantial strain from production losses caused by spoilage. Reducing waste not only saves money for producers and consumers but also alleviates pressure on resources used in food production (Heng, Tan et al. 2024). Furthermore, many food preservation methods—like canning, fermentation, and drying—hold cultural significance, allowing for the enjoyment of seasonal foods throughout the year and promoting diversity in diets (Xiang, Sun-Waterhouse et al. 2019).

However, extending the shelf life of food presents several challenges. One major issue is microbial resistance; as preservation methods evolve, so do the microorganisms threatening food safety. For instance, some bacteria have developed resistance to traditional preservatives, necessitating the exploration of alternative strategies that maintain safety (Zhang, Liu et al. 2021). Additionally, there is a growing consumer preference for natural products, influencing the development of preservation methods. Many conventional preservatives are viewed skeptically, prompting consumers to seek safer, more natural alternatives (Kumar and Rajput 2023). This shift challenges the food industry to innovate while providing effective solutions.

Edible biofilms and coatings are thin layers made from natural materials that can be applied to food products to enhance their quality and safety. These coatings are primarily composed of biopolymers such as proteins, polysaccharides, and lipids, which can be consumed safely along with the food (Walait, Mir et al. 2022). Edible coatings can be applied as a thin film over fresh produce, meats, or baked goods, while biofilms serve a similar function but may offer additional properties, such as improved mechanical strength or barrier characteristics.

The benefits of edible coatings in the food industry are numerous. One key advantage is their ability to extend shelf life. By creating a barrier against oxygen, moisture, and other environmental factors, edible coatings significantly reduce spoilage, helping to minimize food waste—a significant issue in the food supply chain (Perez-Vazquez, Barciela et al. 2023). Moreover, many edible coatings incorporate antimicrobial agents derived from natural sources, such as essential oils or plant extracts, which inhibit the growth of spoilage and pathogenic microorganisms, thereby enhancing food safety (Duda-Chodak, Tarko et al. 2023).

Edible coatings can also be enriched with bioactive compounds, such as vitamins and antioxidants, improving the nutritional profile of food products (Antonino, Difonzo et al. 2024). This feature is particularly appealing in health-conscious markets. Additionally, these coatings help retain moisture within the food, thus maintaining texture and quality, which is especially beneficial for baked goods and fruits that can dry out during storage (Ungureanu, Tihan et al. 2023).

Another important benefit is the reduction of reliance on synthetic packaging materials. By incorporating edible coatings, the food industry can lower its environmental impact, as these coatings are biodegradable and support sustainability goals (Zhang, Liu et al. 2021). Finally, as consumers increasingly seek natural and minimally processed food products, edible coatings enhance product appeal while meeting these demands (Patil, Shams et al. 2023).

Using potato peel waste in edible coatings offers a sustainable solution, addressing both food waste and preservation challenges. These natural coatings can create effective barriers against moisture and oxygen, significantly extending the shelf life of various food products (Mishra and Poonia 2022). Additionally, the antimicrobial properties of bioactive compounds present in potato peels can inhibit the growth of spoilage microorganisms, thereby improving food safety (Hidayat, Sufiawati et al. 2024). This research focuses on the potential of edible coatings derived from potato peels to extend the shelf life of French fries, a popular and perishable food item. By utilizing waste potato peels, this approach offers a sustainable solution that aligns with current trends in food preservation. The objectives of this study are to develop edible coatings from potato peel extracts and evaluate the effectiveness of these coatings in extending the shelf life of French fries.

2. Materials and Methods

Preparation of potato peel material:

Potato peels (Solanum Tuberosum L.) were obtained from a potato chip manufacturing facility in Baghdad, Iraq. The peels were manually inspected to remove contaminants and extraneous matter. Excess moisture was removed by filtration, and the peels were rinsed thoroughly with tap water.

Cleaned potato peels were dried in a ventilated oven at 40°C until completely dehydrated. The dried peels were then ground using a laboratory disc mill (Model SC-7880, Silver Crest, China) and sieved to a particle size of 25 mm. The processed potato peel powder was stored in a tightly sealed PET container at -18°C for subsequent analysis, as shown in the schematic diagram (fig 1.).

Fig 1. Schematic diagram showing the manufacture of edible bioactive coatings from Potato Peels (Solanum Tuberosum L.) according to the three major steps.

Determination Chemical composition of potato peels:

The chemical composition of the potato peels was analyzed using standard methods. Moisture content was determined by drying the samples in a hot air oven at 105°C until constant weight, as described by (Sepelevs, Zagorska et al. 2020). Ash content was measured by incinerating the samples in a muffle furnace at 550°C, following the protocol of (Almeida, Costa et al. 2024). Ether extract (total lipids) was quantified using the Soxhlet extraction method, as outlined by (Rehman, Habib et al. 2004). Crude Fiber was determined by acid-base digestion, as per the procedure given by (Hoque, Alam et al. 2018). Total nitrogen was measured using the Kjeldahl method, and protein content was calculated by multiplying the total nitrogen by a factor of 6.25 (Alam, Rana et al. 2020). Finally, total carbohydrate content was determined by subtracting the sum of moisture, crude protein, crude lipids, ash, and crude Fiber from 100% (Pathak and Agarwal 2017).

Determination of phytochemical profile and antioxidant potential of ethanol extracts from potato peels:

The total phenolic content of potato peel extracts was quantified using the Folin-Ciocalteu method, following the procedure outlined by (Jahanban-Esfahlan, Modaeinama et al. 2019). Gallic acid served as a standard for calibration, and the results were expressed as gallic acid equivalents. The total flavonoid content of the potato peel extracts was quantified using the aluminium chloride colorimetric method described by (Asghar, Yousuf et al. 2016). The results were expressed as rutin equivalents. The absorbance was measured against a blank at 760 nm for total phenolics and 510 nm for total flavonoids using a UV-visible spectrophotometer (Shafii and Sedaghat 2017). The antioxidant activity of the samples was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay, as described by (Kim, Soh et al. 2019). Briefly, 200 μL of each sample was mixed with 2 mL of a DPPH solution (Sigma-Merck, UK). The mixture was incubated for 30 minutes in the dark, and the absorbance was measured at 517 nm using a UV-Vis spectrophotometer. The antioxidant activity was expressed as the percentage inhibition of DPPH radical compared to a control containing methanol instead of the sample.

Preparation of Potato Peel Coating:

Potato peel powder obtained by drying and grinding potato peel waste (Kadam, Tiwari et al. 2015) was subjected to ultrasound treatment at 20 kHz frequency and 100 W power for 10 minutes (Chavan and Kulkarni 2019) and then mixed with distilled water at a ratio of 1:15 (powder: water, w/w) (Jimenez-Champi, Romero-Orejon et al. 2023), with the mixture stirred continuously until the powder was fully dispersed. Glycerol was added to the potato peel-water solution as a plasticizer, at a concentration of 10% based on the weight of the potato peel powder (Yao, Liu et al. 2004), and mixed thoroughly. The resulting potato peel-water-glycerol solution was then poured onto a flat, level surface and allowed to dry at room temperature or in a controlled environment until the desired thickness and dryness were achieved (Chavan and Kulkarni 2019).

French Fry treatment

Potatoes were washed with distilled water before peeling and cut into slices with a thickness of 1 ± 0.2 mm, using a manual cutting machine (Home Collection, Colombia). Subsequently, they were immersed in a solution of 0.05% ascorbic acid, with a potato/acid solution ratio of 2:10, for 15 min to avoid enzymatic browning. Once the contact time was over, the excess product solution was removed with the help of a disposable towel (Yu, Li et al. 2016).

French Fry Coating

The French fries were coated using the method described by (Trujillo-Agudelo, Osorio et al. 2020) using a brush. The coating was applied gently over the surface until the entire surface was covered using the coating solutions prepared following the steps mentioned in the previous paragraphs. The french fry samples were divided into the following treatments:

T1 = Control sample without any addition (negative control sample).

T2 = Addition of potato peel membrane (positive control sample).

The coated French fry samples were conditioned at a refrigerator temperature of 4 ± 1°C and a relative humidity of 50% for 18 hours, with occasional stirring until they were dried.

Determination of Peroxide Value in French Fry:

The method described by (Association of Official Analytical 1990) was followed. 5 g of the fried potato sample was weighed and placed in a volumetric flask. 30 mL of acetic acid-chloroform solution was added and the flask was shaken to dissolve the fat in the solvents. 0.5 mL of saturated potassium iodide solution was added and shaken to allow it

to homogenize. Then, 30 mL of distilled water and 5 drops of starch solution as an indicator were added. Titration was then carried out with 0.01 N sodium thiosulfate solution. The flask was shaken vigorously during titration to extract the iodine from the chloroform layer. The appearance of a purple-blue color indicated the end of the titration. A blank sample containing only the solvents was prepared as a control.
The peroxide value (meq/1000g) was calculated according to the following equation:

$$\textbf{Peroxide value} = [(A - B) * M * 1000] / W$$

Where:
A = Volume consumed during titration of the sample;
B = Volume consumed during titration of the control sample;
M = Molarity of sodium thiosulfate (0.01 N);
W = Weight of the sample (g);

3. Results

The chemical composition of potato peels:

The proximate composition of the potato peels, as presented, revealed that total carbohydrates (67.47%) were the predominant component, followed by total protein (10.50%), total ash and crude fiber (5.16%), moisture (8.05%), total lipids (3.80%) and total ash (4.08%) on a wet weight basis. The protein content of the potato peels was comparable to the value of 9.82% reported by (Hoque, Alam et al. 2018). Additionally, the total ash and total lipid values were similar to those reported by (Pathak and Agarwal 2017), while the crude Fiber and total carbohydrate values were in agreement with the findings of (Srivastava and Gupta 2020). The moisture content of the potato peels was comparable to the value reported by (Alam, Rana et al. 2020).

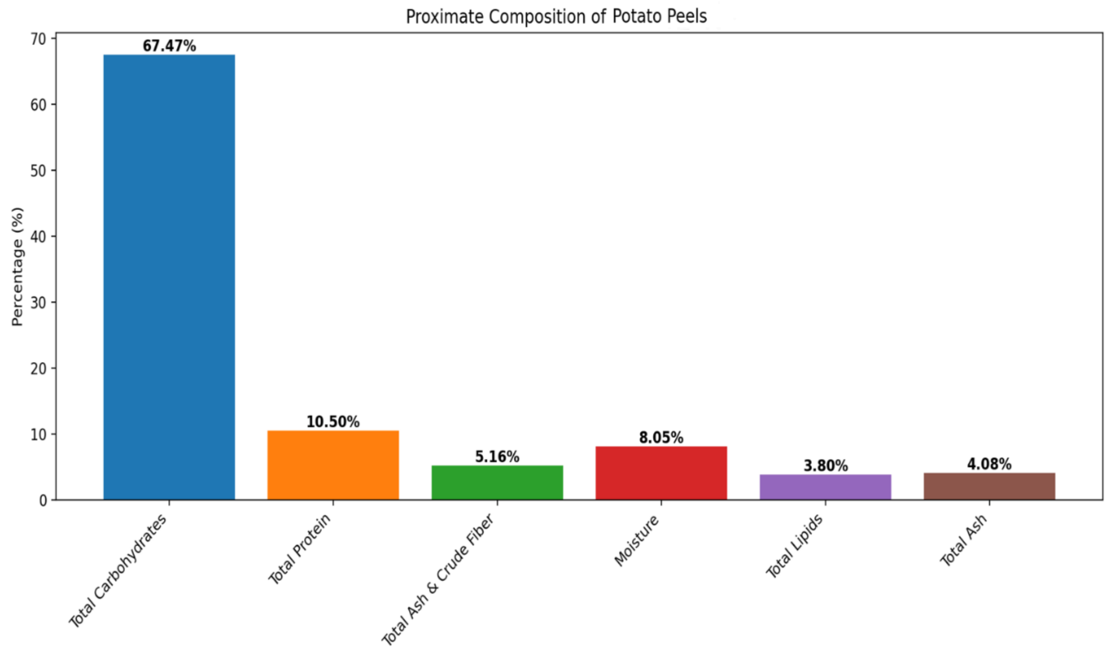

Fig. 2. The chemical composition of potato peels (Solanum Tuberosum L.)

Phytochemical profile and antioxidant potential of ethanol extracts from potato peels:

The ethanolic extract of potato peels was found to contain 4.5 mg gallic acid equivalents (GAE) per gram dry weight (g^{-1} DW) of total phenolics. This finding underscores the rich phytochemical profile of potato peels, which are often considered a waste product in food processing. The observed phenolic content is consistent with previous studies, which have highlighted the effectiveness of ethanol as a solvent for extracting bioactive compounds from various plant materials (Mohdaly 2010, Barchan

2014). Ethanol's polarity and solubility properties facilitate the extraction of phenolic compounds, which are known for their antioxidant, anti-inflammatory, and antimicrobial activities.

In addition to total phenolics, the total flavonoid content of the ethanolic extract was estimated to be 0.13 mg rutin equivalents (RE) per gram dry weight. This result aligns with findings reported by (Friedman 2017, Silva-Beltrán 2017), reinforcing the notion that potato peels are a valuable source of flavonoids, which contribute to the health-promoting properties of food products. Flavonoids are recognized for their potential to scavenge free radicals, thereby playing a crucial role in reducing oxidative stress in biological systems.
Moreover, the antioxidant activity of the ethanolic extract was measured at an impressive 75%, surpassing the ranges reported by (Zhu, Cheng et al. 2016), who documented antioxidant activity percentages of potato peel extracts between 36.38% and 58.62%. This significant enhancement in antioxidant capacity suggests that the extraction process employed in this study effectively concentrated the bioactive compounds responsible for these beneficial effects. Overall, the results indicate that an 80% ethanol extract is particularly effective for isolating antioxidants from dried potato peels. This finding not only validates the use of ethanol as a solvent in the extraction of bioactive compounds but also highlights the potential of potato peels as a functional ingredient in food applications aimed at improving nutritional quality and shelf life. Thus, future research could explore the incorporation of these extracts into various food products, further leveraging their antioxidant properties to enhance health benefits and promote sustainability in the food industry.

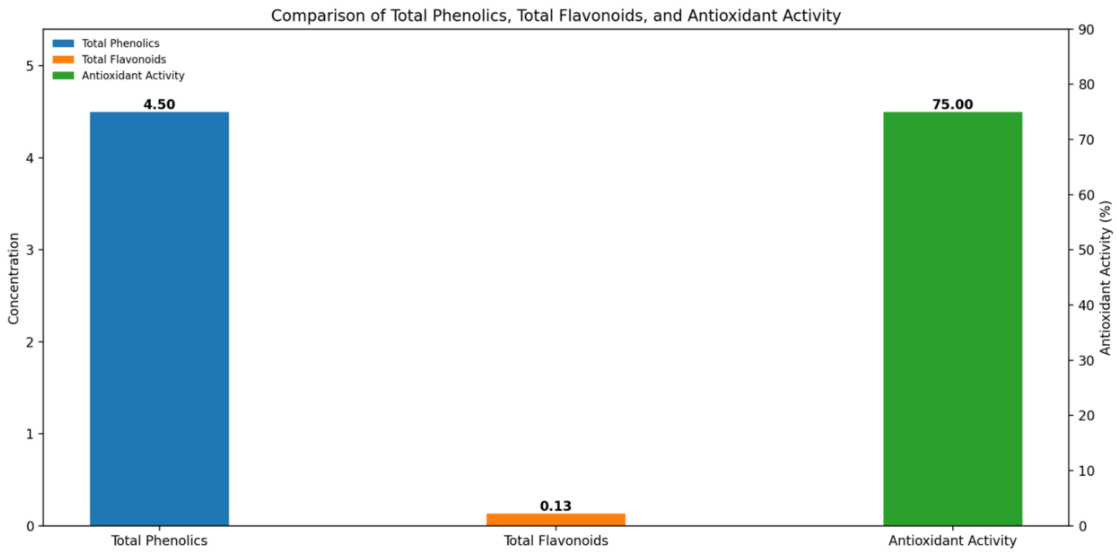

Fig. 3. Total phenolics, flavonoids compounds, and Antioxidant activity of potato peels (Solanum Tuberosum L.) from ethanolic extract.

The Peroxide Value in French Fry:

The peroxide value is typically applied to edible products, animal fats, industrial shortening, and frying oils. It is also used for meat fats and meat products as an indicator of the degree of oxidative rancidity, which is affected by the age of the raw materials as well as oxidation during processing and storage.
Fats undergo oxidation when unsaturated fatty acid chains are present, producing various compounds including free radicals and hydroperoxides. Initially, peroxides increase, but later they are oxidized further into aldehydes and ketones, causing a decrease in peroxide levels in the later stages of oxidation (Association of Official Analytical 1990).
It was observed that frying potatoes led to a decrease in peroxide value. The peroxide value also decreased during refrigerated storage when the fried potatoes were coated. Uncoated samples showed an increase in peroxide value on the 9th day of refrigerated

storage, with a value of 17.5 meq/1000g in treatment T1. However, when the fried potatoes were coated, the peroxide value decreased to 13.7 meq/1000g in treatment T2.
The results agree with the findings of (Qiu, Wang et al. 2018), who observed an increase in peroxide value for fried potato products coated with edible films and stored at 4°C, with the peroxide value continuing to increase over storage time. This is attributed to the fact that fried potatoes and their products are rich in iron, which is a pro-oxidant factor.

4. Conclusion

This study demonstrates the significant potential of potato peel-based edible coatings to extend the shelf life of French fries while preserving product quality and safety. By valorizing this food waste byproduct, the research presents a sustainable and innovative approach to food preservation. The coatings effectively inhibit oxidative rancidity and reduce microbial spoilage, attributed to the bioactive compounds inherent in potato peels. These findings underscore the role of potato peel-based coatings in promoting a more sustainable and environmentally friendly food industry, aligning with consumer preferences for natural and minimally processed products. Additionally, the successful application of these coatings opens avenues for further exploration, including the optimization of coating formulations and their potential use with a broader range of food items. Future research should focus on refining these formulations and assessing their efficacy in various food systems, thereby enhancing the commercial viability of potato peel applications in food preservation. This work not only contributes to reducing food waste but also supports the development of functional food products, fostering a more resilient and sustainable food supply chain.

REFERENCES

1. Association of Official Analytical Chemists (AOAC), 1990. Official methods. AOAC. Washington, DC, USA.
2. Alam, M. K., Z. H. Rana, S. N. Islam and M. Akhtaruzzaman (2020). "Comparative assessment of nutritional composition, polyphenol profile, antidiabetic and antioxidative properties of selected edible wild plant species of Bangladesh." Food Chemistry **320**: 126646.
3. Almeida, P. V., J. C. R. S. Costa, L. M. Gando-Ferreira and M. J. Quina (2024). "Effect of drying and milling industrial potato peel for recovering phenolic and antioxidant compounds: Optimization process and economic evaluation." Journal of Industrial and Engineering Chemistry.
4. Antonino, C., G. Difonzo, M. Faccia and F. Caponio (2024). "Effect of edible coatings and films enriched with plant extracts and essential oils on the preservation of animal-derived foods." J. Food Sci. **89**(2): 748-772.
5. Asghar, M. A., A. Yousuf, A. Ahmed, J. A. Khan and A. K. Qureshi (2016). "Aflatoxins, ochratoxin A and zearalenone contamination in wheat, corn and red chili samples collected from different regions of Pakistan." Food Additives & Contaminants: Part B **9**(2): 92-97.
6. Association of Official Analytical, C. (1990). Official methods. AOAC. Washington, DC, USA.
7. Barchan, D. (2014). "Extraction of phenolic compounds from grape marc and their antioxidant activity." Food Chemistry **155**: 435-440.
8. Chauhan, C., A. Dhir, M. U. Akram and J. Salo (2021). "Food loss and waste in food supply chains. A systematic literature review and framework development approach." Journal of Cleaner Production **295**: 126438.
9. Chavan, Y. S. R. S. and P. R. Kulkarni (2019). Ultrasound-assisted extraction of biopolymers from potato peels, Carbohydrate Polymers, 216, 52-59.
10. Duda-Chodak, A., T. Tarko and K. Petka-Poniatowska (2023). "Antimicrobial Compounds in Food Packaging." Int J Mol Sci **24**(3).
11. Friedman, M. (2017). "Antioxidant and anti-inflammatory activities of potato peel extracts." Journal of Agricultural and Food Chemistry **65**(20): 4378-4385.
12. Fuenmayor, C. A. and F. Licciardello (2024). "The challenges of food preservation materials and technologies for a more sustainable world." Food Packaging and Shelf Life **43**: 101273.
13. Heng, K., K. Tan, A. Chan and C. C. C. Lee (2024). "Food Waste Valorization: Leveraging Singapore’s Zero Waste Master Plan and 30-by-30 Goal." Sustainability **16**(17): 7321.

14. Hidayat, W., I. Sufiawati, M. Satari, R. Lesmana and S. Ichwan (2024). "Pharmacological activity of chemical compounds of potato peel waste (Solanum tuberosum L.) in vitro: A scoping review." J. Exp. Pharmacol. **16**: 61-69.
15. Hoque, M. M., M. K. Alam, H. Khatun, M. A. Aziz and M. M. Rahman (2018). "Nutritional composition and antioxidant activities of 20 selected edible plants from Bangladesh." Food Chemistry **265**: 282-288.
16. Jahanban-Esfahlan, A., S. Modaeinama, S. Abasi, H. Hamishehkar and R. Jahanban-Esfahlan (2019). "Versatile roles of curcumin in cancer prevention and treatment: A critical review of its anti-inflammatory, anticancer, and effects on reproductive cells." Cellular and molecular life sciences **76**(10): 1985-2008.
17. Jimenez-Champi, D., F. L. Romero-Orejon, A. Moran-Reyes, A. M. Muñoz and F. Ramos-Escudero (2023). "Bioactive compounds in potato peels, extraction methods, and their applications in the food industry: a review." CyTA - J. Food **21**(1): 418-432.
18. Kadam, S. U., B. K. Tiwari and C. P. O'Donnell (2015). "Extraction, structure and biofunctional activities of laminarin from brown algae." International Journal of Food Science & Technology **50**(1): 24-31.
19. Kim, J., S. Y. Soh, H. Bae and S.-Y. Nam (2019). "Antioxidant and phenolic contents in potatoes (Solanum tuberosum L.) and micropropagated potatoes." Appl. Biol. Chem. **62**(1).
20. Kumar, R. and R. Rajput (2023). "Role of natural preservatives and their effect on food's shelf life." Curr. J. Appl. Sci. Technol. **42**(47): 7-19.
21. Mishra, P. and A. Poonia (2022). Potato Waste-Based Packaging Edibles: A Sustainable Approach for Food Preservation. Edible Food Packaging : Applications, Innovations and Sustainability. A. Poonia and T. Dhewa. Singapore, Springer Nature Singapore**:** 149-156.
22. Mohdaly, N. A. (2010). "Antioxidant activity and phenolic content of some selected medicinal plants." Journal of Food Science and Technology **47**(3): 303-308.
23. Olvera-Aguirre, G., Á. T. Piñeiro-Vázquez, J. R. Sanginés-García, A. Sánchez Zárate, A. A. Ochoa-Flores, M. R. Segura-Campos, E. Vargas-Bello-Pérez and A. J. Chay-Canul (2023). "Using plant-based compounds as preservatives for meat products: A review." Heliyon **9**(6): e17071.
24. Pathak, P. D. and N. Agarwal (2017). "Phytochemical analysis and assessment of antioxidant properties of Bacopa monnieri." Journal of Pharmacy Research **11**(6): 694-700.
25. Patil, V., R. Shams and K. K. Dash (2023). "Techno-functional characteristics, and potential applications of edible coatings: A comprehensive review." Journal of Agriculture and Food Research **14**: 100886.
26. Perez-Vazquez, A., P. Barciela, M. Carpena and M. Prieto (2023). "Edible coatings as a natural packaging system to improve fruit and vegetable shelf life and quality." Foods **12**(19): 3570.
27. Qiu, G., D. Wang, X. Song, Y. Deng and Y. Zhao (2018). "Degradation kinetics and antioxidant capacity of anthocyanins in air-impingement jet dried purple potato slices." Food Research International **105**: 121-128.
28. Rehman, Z.-U., F. Habib and W. H. Shah (2004). "Utilization of potato peels extract as a natural antioxidant in soy bean oil." Food Chem. **85**(2): 215-220.
29. Sepelevs, I., J. Zagorska and R. Galoburda (2020). "A food-grade antioxidant production using industrial potato peel by–products."
30. Shafii, Z. A. B. F. B. l. F. C. and N. Sedaghat (2017). Isolation, identification, and molecular characterization of endophytic bacteria from the roots of Chlorophytum borivilianum, PloS one, 12(6), e0179488.
31. Silva-Beltrán, A. E. (2017). "Antioxidant and antimicrobial activities of potato peel extracts." Food Science and Technology International **23**(4): 306-313.
32. Srivastava, P. M. N. Y. D. and R. Gupta (2020). Physicochemical, functional, and antioxidant properties of potato peel powder, Food Measure, 14, 2274-2284.
33. Trujillo-Agudelo, S., A. Osorio, F. Gómez, J. Contreras-Calderón, M. Mesías-Garcia, C. Delgado-Andrade, F. Morales and O. Vega-Castro (2020). "Evaluation of the application of an edible coating and different frying temperatures on acrylamide and fat content in potato chips." Journal of Food Process Engineering **43**(5): e13198.
34. Ungureanu, C., G. Tihan, R. Zgârian and G. Pandelea (2023). "Bio-Coatings for Preservation of Fresh Fruits and Vegetables." Coatings **13**(8): 1420.
35. Walait, M., H. R. Mir and K. Anees (2022). "Edible biofilms and coatings; its characterization and advanced industrial applications." Natural Resources for Human Health **3**(1): 28-37.
36. Xiang, H., D. Sun-Waterhouse, G. I. N. Waterhouse, C. Cui and Z. Ruan (2019). "Fermentation-enabled wellness foods: A fresh perspective." Food Science and Human Wellness **8**(3): 203-243.

37. Yao, C.-H., B.-S. Liu, C.-J. Chang, S.-H. Hsu and Y.-S. Chen (2004). "Preparation of networks of gelatin and genipin as degradable biomaterials." Materials Chemistry and Physics **83**(2): 204-208.
38. Yu, L., J. Li, S. Ding, F. Hang and L. Fan (2016). "Effect of guar gum with glycerol coating on the properties and oil absorption of fried potato chips." Food Hydrocolloids **54**: 211-219.
39. Zhang, X., X. Liu, C. Yang, T. Xi, J. Zhao, L. Liu and K. Yang (2021). "New strategy to delay food spoilage: Application of new food contact material with antibacterial function." Journal of Materials Science & Technology **70**: 59-66.
40. Zhu, X., Y. Cheng, P. Chen, P. Peng, S. Liu, D. Li and R. Ruan (2016). "Effect of alkaline and high-pressure homogenization on the extraction of phenolic acids from potato peels." Innovative Food Science & Emerging Technologies **37**: 91-97.