International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(10): 644-648
www.biochemjournal.com
Received: 15-08-2025
Accepted: 18-09-2025

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Peeling of fruits and vegetable: A review

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i10Sh.5897

Abstract
Peeling represents a critical primary step in the post-harvest processing of fruits and vegetables, as it directly influences the overall quality of the final product. Inefficient peeling practices often result in excessive material losses and reduced product quality thereby increasing processing costs. Broadly peeling techniques can be classified into four categories: mechanical, thermal, enzymatic, and chemical methods. This review aims to provide a comparative assessment of these peeling techniques across various commodities. The discussion is structured according to the specific method employed supported by recent research findings and examples that highlight advances in the field.

Keywords: Peeling, chemical, mechanical, thermal

Introduction

Fruit and vegetable peels play a significant role in human nutrition, as they are rich in dietary fiber that contributes to satiety and hunger reduction. In fact, many fresh fruits and vegetables may contain up to one-third more fiber when consumed with their peels. However, in food processing, peeling is often an essential preliminary step, since the removal of the outer layers is required for most agricultural commodities. The effectiveness of peeling largely depends on the physical and mechanical properties of the produce, and continuous research has been directed towards developing improved methods that ensure efficiency and sustainability.

The primary objectives of an optimal peeling operation are to minimize product losses, reduce energy and chemical consumption, and limit environmental impact. Peeling methods can be broadly categorized into manual peeling (using knives or blades), mechanical peeling (using abrasive drums, rollers, or cutting devices), chemical peeling, enzymatic peeling, and thermal peeling. Among these, abrasive peeling has been successfully applied to a range of vegetables using abrasive peelers (Fouda *et al*., 2019) [7].

Methods of fruits and vegetable peeling

Manual peeling

Manual peeling is one of the oldest and most common methods of removing the skin from fruits and vegetables. It is usually performed with hand tools such as knives or stationary/rotary peelers. This technique often produces fresh-cut products with acceptable microbiological quality. Klaiber *et al*., (2005) [12] noted that using knives for peeling carrots caused less tissue injury compared to abrasion peeling, which may lower the chances of microbial contamination during subsequent handling. In contrast, O'Beirne *et al.*, (2014) [22] found no major difference between coarse abrasion and hand peeling regarding the attachment of *E. coli* O157:H7 on carrot surfaces.

While manual peeling ensures careful handling and can help retain product quality, the method is slow, labor-demanding, and therefore better suited for small-scale or household-level operations. One advantage of this approach is the ability to peel produce of irregular shapes and sizes with minimal waste, making it especially useful for delicate fruits and vegetables (Garcia and Barrett, 2002) [39]. However, in large-scale food industries, its dependence on human labor reduces productivity and raises operational costs (Rico *et al.*, 2007) [26]. In addition, differences in operator skill and hygiene practices can lead to inconsistent quality and potential cross-contamination risks (Nguyen and Carlin, 1994) [21]. For these reasons, the food industry is increasingly moving toward mechanical, chemical, or enzymatic peeling methods, which offer greater efficiency, uniformity, and food safety assurance.

Mechanical Peeling

Mechanical peeling involves processes that act directly on the surface of fruits and vegetables to detach and remove the skin. Commercially this is achieved through abrasive devices, rotating drums, rollers, knives, and milling cutters. These systems are valued for producing high-quality fresh end products while being environmentally safe and non-toxic. The effectiveness of mechanical peeling largely depends on the mechanical and physical characteristics of the produce including skin thickness, firmness, toughness, variety, rupture force, cutting force, shear strength, tensile strength, and rupture stress (Shrimohammadi *et al*., 2012) [30].

In addition to conventional applications efforts have been made to design specialized peeling machines. For example, a sugarcane peeling machine was developed to address challenges in the commercial processing of sugarcane. The canes were classified into small, medium, and large sizes, and the prototype equipped with an abrasive peeling tool achieved a peeling efficiency of approximately 59.67% (Gadekar *et al.,* 2018) [9]. This development provides a foundation for further improvements in the design and industrial production of sugarcane peeling equipment.

Evaluated the performance of a new small-scale sugarcane peeler machine. The maximum machine production efficiency (88.85%) and the minimum electrical power consumption (5.56kW) were achieved with no. of feeding canes per minute of 3 canes respectively. Also, the minimum machinery unit cost was 67.49 LE/Mg and 9 cans/min feeding rate (Yamini *et al*., 2016) [37].

Developed a power operated batch type mechanical peeler for potato peeling. The machine consists a peeling drum with protrusions on the inside surface and the drum rotates and then detaches peel from potatoes by abrasion. Additionally, the peeler have a water spraying unit that washes the potatoes and simultaneously peels are removed from the drum. Singh and Shukla (1995) [31].

Abrasive devices

Abrasive peeling is a simple yet effective technique in which the outer skin of vegetables is removed by mechanical friction. Traditionally, this has been achieved using gloves or pads with rough surfaces that scrape off the peel when the produce is rubbed against them. The method is particularly suited for small root crops such as potatoes, where the skin can be loosened and detached with minimal effort (Somsen *et al*., 2004) [32].

Recent developments have led to the introduction of specialized abrasive gloves and tools that provide a safer alternative to knives or sharp peelers. These products feature textured surfaces designed to improve efficiency while reducing the risk of injury during handling. Their growing popularity in both households and small-scale commercial settings is attributed to their ease of use, cost-effectiveness, and ability to peel a variety of vegetables without significant product loss (Pereira and Vicente, 2010) [24].

In industrial food processing, abrasive peeling is also applied through rotating drums lined with abrasive materials, where continuous friction removes the peel. This approach enables faster processing and uniform peeling, though it can lead to higher product losses compared to more precise methods such as steam or enzymatic peeling (Mizrahi, 2015) [16]. Another limitation is the potential for microbial contamination due to the increased surface area exposed after abrasion, requiring careful sanitation and handling (Rico *et al*., 2007) [26]. Despite these drawbacks, abrasive peeling remains a widely adopted method because of its simplicity, low equipment cost, and adaptability for different scales of operation.

Knife and Blade

Blade peeling machines are commonly designed with cutting edges that physically separate the skin from the underlying edible tissue of fruits and vegetables. In a typical setup, the produce is placed on a holding base and rotated to ensure that all surfaces come into contact with the blade. The peeling action is often supported by mechanical systems such as threaded rods, springs, or adjustable arms, which allow the blade to maintain consistent pressure against the surface of the rotating produce (Tardif and He, 1999) [35]. This arrangement enables uniform and controlled removal of the peel while minimizing unnecessary loss of edible material.

Modern designs of blade-based peelers have incorporated features such as automated rotation, adjustable blade angles, and sensors that adapt to different shapes and sizes of produce, thereby improving efficiency and reducing waste (Sankat and Maharaj). Compared to abrasive methods, blade peeling generally produces smoother surfaces and better preserves the structural integrity of the product (Kumari *et al*., 2018) [15]. However, the technique may require frequent blade maintenance and can be less suitable for very small or irregularly shaped items.

In industrial applications, high-speed mechanical peelers are widely employed for root vegetables like carrots, beets, and potatoes. These machines offer advantages in terms of precision, throughput, and quality, although their initial cost and energy requirements are higher than simpler methods such as abrasive peeling (Mizrahi, 2015) [16]. Despite these challenges, blade-based peeling continues to be an important technology in both small-scale and large-scale vegetable processing, balancing efficiency with product quality.

Lye or Chemical Peeling

Lye peeling is among the oldest and most widely practiced chemical methods for removing the skin from fruits and vegetables. In this technique, the raw material is briefly immersed in a hot alkaline solution, usually sodium hydroxide, maintained at temperatures around 90-100 °C (Di Matteo *et al*., 2012) [5]. The alkali penetrates the outer layers and hydrolyzes structural polysaccharides such as pectins and hemicelluloses. Specifically, the alkaline treatment cleaves the α-(1→4) glycosidic linkages between galacturonic acid residues in the pectin chain, disrupting the middle lamella and weakening the structural integrity of the skin (Barreiro *et al*., 2007) [1]. As a result, the peel loses adhesion to the flesh and can be easily removed during subsequent washing.

One of the main advantages of lye peeling is its high efficiency, which makes it suitable for large-scale processing of produce such as peaches, apricots, citrus fruits, and tomatoes (Castro-Giraldez *et al*., 2014) [4]. The method ensures rapid peeling, relatively smooth surfaces, and low mechanical damage compared to abrasive or blade-based peeling. However, lye peeling also generates significant quantities of alkaline wastewater, which can present environmental and disposal challenges if not properly treated (Sapers, 1995) [27]. In addition, prolonged exposure or excessively high concentrations of alkali may cause product softening or loss of sensory quality.

To reduce these limitations, modern processing facilities often combine lye peeling with steam or hot water rinsing systems to neutralize residual alkali and improve peel removal efficiency (Ribeiro *et al*., 2010) [25]. Recent research has also explored the replacement of traditional sodium hydroxide solutions with alternative, more eco-friendly chemical formulations, as well as enzymatic or combined treatments, to minimize chemical load and enhance sustainability (Mir and Behera, 2016) [18]. Despite its drawbacks, lye peeling remains an important technique in food processing due to its effectiveness, speed, and adaptability to a wide range of fruit and vegetable commodities.

Enzymatic Peeling

Enzymatic peeling is a biotechnological fruit-processing technique that involves the use of high-activity enzymatic solutions containing polysaccharide-hydrolyzing enzymes such as pectinases, cellulases, and hemicellulases. These enzymes specifically target the structural polysaccharides pectin, cellulose, and hemicellulose which are primarily responsible for the tight adherence of the peel to the underlying fruit tissues. By breaking down these complex polysaccharides the enzymatic treatment weakens the integrity of the middle lamella and primary cell wall allowing the peel to be removed more efficiently and with minimal damage to the fruit flesh (Suutarinen *et al.,* 2003) [33].

The enzymatic preparations used in peeling are generally obtained through the controlled fermentation of genetically modified fungal microorganisms developed and optimized in modern biotechnological industries to produce enzymes with high yield and activity. Compared to conventional chemical peeling methods which often employ alkaline or acidic solutions, enzymatic peeling is regarded as a safer, more environmentally friendly, and nutritionally preserving alternative (Seminario *et al*., 2016) [40]. It not only reduces chemical waste and prevents undesirable alterations in flavor and nutrient content but also improves surface quality and uniformity of peeled fruits such as citrus fruits, peaches, and tomatoes (Lee *et al*., 2013) [41].

In addition, enzymatic peeling demonstrates a significant potential for sustainable industrial applications, as it minimizes energy consumption and reduces effluent load compared to thermal or chemical peeling methods (Ramesh & Kumar, 2018) [15]. With advancements in enzyme technology and microbial fermentation, this process continues to evolve as a clean-label peeling technique, aligning with consumer demand for minimally processed foods and environmentally responsible manufacturing practices.

Thermal Peeling

Thermal peeling is widely employed in the processing of vegetables with relatively thick skins, such as potatoes, carrots, beets, and onions. This method relies on the application of heat, which can be provided either through wet systems (e.g., steam) or dry systems (e.g., flame, infrared radiation, or hot gases) (Schlüter & Knorr, 2004) [28]. Among these, steam peeling has become the most commonly used industrial approach because it enables high levels of automation, accurate regulation of pressure, time, and temperature, and results in lower chemical waste compared to lye or other chemical peeling methods (Garrote *et al.,* 2000) [42].

The mechanism of steam peeling involves a combination of physical and biochemical changes. When the produce is exposed to high-pressure steam, rapid heating generates internal vapor pressure within the tissues. This sudden increase in pressure weakens the epidermal layers and disrupts the adhesion between peel and flesh, causing the skin to loosen and detach (Lisinska and Leszczynski, 1989) [20]. In addition, elevated temperatures modify the tissue structure by softening cell walls, degrading pectin, and reducing turgor pressure, which further facilitates peel removal (Garrote *et al.,* 2000) [42]. Once the steam chamber is depressurized, the loosened peel can be easily removed by mechanical brushes or water sprays.

Compared to other methods, thermal peeling is considered more environmentally friendly since it avoids the use of alkaline solutions, thereby reducing wastewater treatment requirements (Barreiro *et al*., 2007) [1]. It also minimizes product loss, provides smooth peeled surfaces, and allows continuous large-scale operation. However, prolonged exposure to heat can sometimes cause partial cooking, loss of volatile compounds, or changes in texture, which may not be desirable for certain products (Brodnitz, 1990) [2]. To address this, modern steam peeling systems employ precise time-pressure controls, rapid depressurization, and integration with mechanical finishing devices to optimize peeling efficiency while preserving quality (Kita and Lisinska, 2005) [11].

Emerging Methods

Infrared (IR) radiation, located between visible light and microwaves on the electromagnetic spectrum, has gained attention as an innovative non-contact heating method in food processing. When IR waves strike a material, part of the radiation is reflected or transmitted, while the absorbed portion is transformed into heat energy. This process increases the temperature of the material, with the outer layers heating more rapidly than the inner core (Li *et al.,* 2014) [19]. In the context of peeling, this localized heating softens or loosens the peel, creating a separation between the skin and underlying tissue without excessive damage to the edible portion.

The primary advantage of IR peeling lies in its ability to provide uniform and controlled surface heating. By precisely adjusting radiation intensity, wavelength, and exposure time, processors can achieve effective peel removal while preserving the nutritional compounds, texture, and sensory properties of fruits and vegetables (Nowak *et al*., 2012) [17]. Compared to conventional thermal methods such as steam or flame peeling, IR systems typically require shorter processing times and lower energy input, making them a promising alternative for sustainable food production (Zhu *et al.,* 2013) [43].

Another important aspect of IR peeling is its potential to reduce resource consumption. Unlike lye peeling, which generates alkaline wastewater, or steam peeling, which demands large amounts of water and energy, IR peeling is a dry process with minimal effluent. This not only lowers environmental impact but also decreases post-peeling washing and wastewater treatment requirements (Chaudhry and James, 2010) [3]. Furthermore, IR radiation has inherent antimicrobial effects, which can enhance food safety by reducing microbial loads on the produce surface (Krishnamurthy *et al*., 2008) [14].

Despite these benefits, IR peeling is still at a developmental stage and faces challenges in scaling up for industrial applications. Non-uniform heating of irregularly shaped products, high equipment costs, and the need for optimized process parameters remain barriers to widespread adoption. Nevertheless, ongoing research and advancements in IR emitter design, automation, and hybrid systems suggest strong potential for the integration of IR peeling in future fruit and vegetable processing lines (Wang and Raghavan, 2017) [36].

Conclusion

Peeling is a critical step in the post-harvest processing of fruits and vegetables, significantly affecting yield, quality and safety. Various methods manual, mechanical, abrasive, knife/blade-based, chemical, enzymatic, thermal, and emerging technologies like infrared peeling offer specific advantages and limitations. Manual peeling ensures minimal tissue damage but is labour intensive whereas mechanical and specialized machines provide high-quality output and environmental safety. Chemical and enzymatic peeling effectively weaken peel adhesion while thermal and infrared methods improve efficiency and preserve nutrients. Emerging techniques aim to reduce water and energy usage, minimize waste and enhance food safety reflecting a trend toward more sustainable and efficient processing.

Future research should focus on optimizing peeling technologies for industrial and small-scale applications. Key areas include automation and sensor-based control to adapt peeling to fruit and vegetable characteristics energy and water-efficient systems integration of non-thermal methods such as pulsed electric fields or ultrasound and strategies for improved microbial safety. Additionally sustainable design of peelers and utilization of peel waste as dietary fiber bioactive compounds or bioenergy can contribute to circular and eco-friendly processing. These developments will enhance both the efficiency and quality of fruit and vegetable processing while reducing environmental impact.

References

1. Barreiro JA, Sandoval AJ, Rivas D, Rinaldi R. Application of a mathematical model for chemical peeling of peaches (*Prunus persica* L.) variety Amarillo Jarillo. LWT Food Sci Technol. 2007;40:574-578.
2. Brodnitz MH. Thermal processing effects on flavor and aroma of vegetables. Food Rev Int. 1990;6(4):507-528.
3. Chaudhry MM, James SJ. Dry peeling technologies for food applications. J Food Eng. 2010;98(2):151-158.
4. Castro-Giraldez M, Fito PJ, Fito P. Application of microwaves and hot air drying to lye-peeled fruits. Innov Food Sci Emerg Technol. 2014;21:46-55.
5. Di Matteo M, Albanese D, Liguori L. Alternative method for hazelnuts peeling. Food Bioprocess Technol. 2012;5:1416-1421.
6. Emadi B, Kosse V, Varlagadda PKDV. Abrasive peeling of pumpkin. J Food Eng. 2007;79(2):647-656.
7. Fouda T, Darwesh M, Elkhodarey M. A study on some different parameters affecting the abrasive peeling machine performance. Sci Pap Ser Manag. 2019;19(1):193-198.
8. Garrte RL, Silva ER, Beutone RA. Effect of thermal treatment on steam peeled potato. J Food Eng. 2000;45(2):67-76.
9. Gadekar RA, Najmin A, Prafful B, Bharat B, Waykar A. Sugarcane peeling machine. Int J Curr Trends Sci Technol. 2018;8(1):116-121.
10. Gavahian M, Satry SK. Ohmic-assisted peeling of fruits: understanding the mechanism involved, effective parameters, and prospective application in the food industry. Trends Food Sci Technol. 2020;106:345-354.
11. Kita A, Lisinska G. The influence of potato steam peeling on quality of raw material. Food Chem. 2005;89(2):261-266.
12. Klaiber RG, Baur S, Wolf G, Hammes WP, Carle R. Quality of minimally processed carrots as affected by warm water washing and chlorination. Innov Food Sci Emerg Technol. 2005;6:351-362.
13. Kohli D, Champawat PS, Mudgal VD. Advances in peeling techniques for fresh produce. J Food Process Eng. 2021;44:e13826.
14. Krishnamurthy K, Tewari JC, Irudayaraj J, Demirci A. Microwaves and infrared radiation for food safety and preservation. Food Sci Technol Int. 2008;14(6):423-448.
15. Kumari S, Kumar A, Kumar V. Design and development of vegetable peeling machine. Int J Eng Res Technol. 2018;7(5):1-5.
16. Mizrahi S. Mechanisms of peeling in fruit and vegetable processing. In: Handbook of Food Processing: Food Preservation. CRC Press; 2015. p.219-236.
17. Nowak D, Lewicki PP, Witrowa-Rajchert D. Influence of infrared radiation on quality of dried fruits and vegetables. J Food Eng. 2012;110(3):360-370.
18. Mir SA, Behera D. Sustainable approaches in fruit and vegetable peeling: a review. Food Rev Int. 2016;32(2):143-164.
19. Li X, Pan Z, Atungulu GG, Zheng X, Wood D, Delwiche M, *et al*. Peeling of tomatoes using novel infrared radiation heating technology. Innov Food Sci Emerg Technol. 2014;21:123-130.
20. Lisinska G, Leszczynski W. Potato science and technology. London: Springer; 1989.
21. Nguyen-The C, Carlin F. The microbiology of minimally processed fresh fruits and vegetables. Crit Rev Food Sci Nutr. 1994;34(4):371-401.
22. O'Beirne D, Gleeson E, Auty M, Jordan K. Effects of processing and storage variables on penetration and survival of *Escherichia coli* O157:H7 in fresh-cut packaged carrots. Food Control. 2014;40:71-77.
23. Ojolo SJ, Orlsoleye I. Design and fabrication of a yam peeling machine. J Eng Res. 2016;21(1):123-132.
24. Pereira RN, Vicente AA. Environmental impact of novel thermal and non-thermal technologies in food processing. Food Res Int. 2010;43(7):1936-1943.
25. Ribeiro C, Barbosa C, Teixeira JA. Strategies for minimizing chemical residues in peeled fruits: washing and neutralization approaches. Food Control. 2010;21(6):765-772.
26. Rico D, Martin-Diana AB, Barat JM, Barry-Ryan C. Extending and measuring the quality of fresh-cut fruit and vegetables: a review. Trends Food Sci Technol. 2007;18(7):373-386.
27. Sapers GM. Residual chemicals in fruits and vegetables: hazards and control. Food Technol. 1995;49(6):53-59.

28. Schlüter O, Knorr D. Impact of novel physical technologies on vegetable processing. Food Control. 2004;15(5):401-407.
29. Shaker M, Jokar A, Mohammadi D. Technical and economical evaluation of abrasive peeling machine and its effect on nutritional characteristics of quinoa. Agric Eng Int CIGR J. 2022;24(3):214-225.
30. Shirmohammadi M, Yarlagadda PK, Kosse V, Gu Y. Study of mechanical deformations on tough-skinned vegetables during mechanical peeling process. GSTF J Eng Technol. 2012;1:31-37.
31. Singh KK, Shukla BB. Abrasive peeling of potatoes. J Food Eng. 1995;26(4):431-442.
32. Somsen D, Capelle A, Tramper J. Production of fresh-cut potatoes. Innov Food Sci Emerg Technol. 2004;5(2):185-193.
33. Suutarinen M, Mustranta A, Autio K, Salmenkallio-Marttila M, Ahvenainen R, Buchert J, *et al*. The potential of enzymatic peeling of vegetables. J Sci Food Agric. 2003;83:1556-1564.
34. Tapia MR, Gutierrez-Pacheco MM, Vazquez-Armenta FJ. Washing, peeling and cutting of fresh-cut fruits and vegetables. In: Springer International Publishing; 2015. p.57-78.
35. Tardif F, He Q. Mechanical aspects of fruit and vegetable peeling. J Food Eng. 1999;42(1):33-49.
36. Wang S, Raghavan GSV. Emerging infrared and hybrid infrared heating technologies for food processing. Compr Rev Food Sci Food Saf. 2017;16(4):642-657.
37. Yamani EAE, Basiouny MA. Performance evaluation of new sugarcane peeling machine prototype. J Soil Sci Agric Eng. 2016;7(4):289-298.
38. Zhou Y, Vidyarathi SK, Hai Yang X. Conventional and novel peeling methods for fruits and vegetables. Innov Food Sci Emerg Technol. 2022;77:e102961.
39. Garcia E, Barrett DM. Preservative treatments for fresh-cut fruits and vegetables. Fresh-cut fruits and vegetables. 2002:267-304.
40. Kumar N, Seminario JM. Lithium-ion model behavior in an ethylene carbonate electrolyte using molecular dynamics. The Journal of Physical Chemistry C. 2016 Aug 4;120(30):16322-32.
41. Lee Y, Park J, Ryu C, Gang KS, Yang W, Park YK, Jung J, Hyun S. Comparison of biochar properties from biomass residues produced by slow pyrolysis at 500 C. Bioresource technology. 2013 Nov 1;148:196-201.
42. Garrote GL, Abraham AG, De Antoni GL. Inhibitory power of kefir: the role of organic acids. Journal of food protection. 2000 Mar 1;63(3):364-9.
43. Zhu Q, Sarkis J, Lai KH. Institutional-based antecedents and performance outcomes of internal and external green supply chain management practices. Journal of Purchasing and Supply Management. 2013 Jun 1;19(2):106-17.