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A Comprehensive Review on Banana Peeling Technologies

Dr. A. Lovelin Jerald
Department of Food Processing and Preservation Technology.
Avinashilingam Institute for Home Science and Higher Education for Women.
Coimbatore,Tamil Nadu
lovelin_fppt@avinuty.ac.in

Nagalakshmi S
Department of Food Processing and Preservation Technology.
Avinashilingam Institute for Home Science and Higher Education for Women.
Coimbatore,Tamil Nadu
22uef015@avinuty.ac.in

Santhiya N
Department of Food Processing and Preservation Technology.
Avinashilingam Institute for Home Science and Higher Education for Women.
Coimbatore,Tamil Nadu
22uef023@avinuty.ac.in

***Abstract*—Banana peeling is an important step after harvest in banana processing industries. It directly affects productivity, hygiene, and product quality. Guo et al. (2020) reported that poor mechanization in banana post-harvest operations leads to significant processing losses and a reliance on labor. Traditional manual peeling methods are common, but they require a lot of labor and often result in uneven peel removal, pulp damage, and contamination risks. Kumar et al. (2018) and Patel et al. (2018) highlighted these issues. Recent research has turned to mechanized and automated banana peeling systems to boost efficiency and meet food safety standards. Edeh et al. (2025) pointed out that automation in banana peeling increases throughput and lowers human involvement in processing lines.**

This review looks closely at current banana peeling technologies, such as mechanical, compression-assisted, and pneumatic-based systems. It gives special attention to horizontally oriented banana peelers. Defraeye et al. (2020) and Rahman and Islam (2019) identified pneumatic actuation as a promising method because it applies controlled force and is suitable for hygienic food processing environments. The literature reviewed suggests that a horizontal pneumatic banana peeler fits well with this project and can be a practical and affordable option for small- and medium-sized banana processing units. The review brings together recent developments, identifies common challenges, and suggests future steps for banana peeling mechanization.

Keywords—Banana peeling, Pneumatic peeling systems, Banana processing machinery, Post harvest mechanization, Food processing automation

I. INTRODUCTION

Bananas (Musa spp.) are among the most consumed fruits worldwide. They serve as a staple food and are an important economic crop in many tropical and subtropical countries. Global banana production supports both domestic consumption and export markets, greatly contributing to food security and rural livelihoods (FAO, 2017; Guo et al., 2020). Despite their importance, post-harvest losses are still high, ranging from 20% to 40% in some areas. These losses are primarily due to manual handling, inefficient processing, and poor post-harvest infrastructure (FAO, 2019).

Peeling is one of the most important steps in banana processing. Manual peeling is slow and physically demanding. It often causes pulp damage and wastage, especially in small-scale operations where labor and time are limited (Kumar et al., 2018; Patel et al., 2018; Edeh et al., 2025). Additionally, differences in fruit size, shape, and ripeness make manual peeling even more challenging, affecting the uniformity and quality of processed products like banana slices, chips, or sticks.

To tackle these challenges, mechanized banana processing technologies, including semi-automatic and fully automatic peeling machines, have been created. These systems reduce reliance on manual labor, increase throughput, and improve product consistency and quality (Manomai et al., 2024). Recent progress in robotics, pneumatic and hydraulic actuation, and image-guided control systems has allowed for careful handling of bananas. This minimizes bruising and maximizes peel removal efficiency

(Zhang et al., 2020; Chen et al., 2024; Zhu & Spachos, 2021).

Furthermore, low-cost tabletop and compact peeling devices have become available. They make mechanized banana processing accessible to small businesses, research labs, and educational institution. These technologies are especially useful in regions where large-scale machinery is not practical due to financial or space limitations.

In addition to peeling, post-harvest losses in bananas also happen during shelling, cleaning, sorting, and grading. Poorly designed manual and semi-automatic processes lead to mechanical damage, microbial contamination, and uneven quality. These issues lower the marketable yield and shelf life of bananas (FAO, 2019). Therefore, combining mechanization with smart processing technologies is vital for improving efficiency, reducing waste, and increasing the economic value of bananas throughout the supply chain.

The development and use of mechanized banana processing systems support global efforts to improve post-harvest management, cut down food loss, and strengthen banana value chains. By integrating mechanical design, actuation systems, and AI-assisted control, these technologies provide a sustainable way to modernize banana processing while ensuring product quality and safety (Chen et al., 2024).

II. Banana Peeling Technologies

A. *Conventional Methods*

Conventional banana peeling methods mainly rely on manual labor. Workers take off the peel using their hands or simple knives, often cutting along the natural ridges of the banana. This method is popular because it is simple, inexpensive, and requires minimal equipment (FAO, 2017). Manual peeling is common in households, small processing units, and local markets where machines are not practical. However, it is time-consuming and requires a lot of labor, especially when processing large quantities of bananas. Additionally, manual peeling often causes pulp damage and waste, which lowers the overall yield of processed products like banana chips, slices, or sticks (Edeh et al., 2025). Variations in banana size, shape, and ripeness further complicate manual peeling, making it hard to achieve uniformity.

Early attempts to reduce labor intensity led to simple semi-automatic devices like roller-based peelers or knife-assisted peelers. These devices help the operator by partially mechanizing the peeling process, but they still need manual positioning and handling of the fruit (Kumar et al., 2018; Patel et al., 2018). Semi-automatic machines improve efficiency a bit compared to fully manual methods, but their throughput is low, and they cannot entirely prevent pulp damage. Despite these downsides, conventional manual and semi-automatic methods are still widely used in small-scale banana processing, especially in developing countries where cost and infrastructure challenges limit the use of fully automated peeling technologies (Edeh et al., 2025).

Fig. 1 Manual peeling

(*Source: https://share.google/VmWr9BHaswhLGTkld)*

B. *Semi-Automatic and Fully Automated Mechanisms*

To tackle the limits of traditional peeling, semi-automatic banana peeling machines have been created to boost efficiency and cut down on labor. These machines usually need manual placement of bananas. After that, mechanized parts like cutting blades or rollers take care of the peeling. Semi-automatic peelers help minimize pulp damage and ensure more consistent peel removal compared to fully manual methods (Patel et al., 2018). They work well for small to medium-scale processing units, offering some mechanization without needing a large investment.

Fully automated peeling systems take productivity a step further by using conveyors, deployable mechanisms, and robotic arms to manage bananas without any manual help. These machines often use rotary knives, deployable arms, or peeling rollers to achieve uniform peeling and keep product quality high. Fully automated peelers can adapt to banana size, shape, and ripeness, making them ideal for industrial-scale processing, where high throughput and consistency matter (Sharma & Tewari, 2019). By combining mechanical accuracy with continuous operation, these systems significantly lessen the need for labor and improve overall processing efficiency.

Fig.2 Automated peeling machine
(Source: https://share.google/Ilj2EdU6EDtb9uj0L)

C. *Pneumatic and Hydraulic Methods*

Modern banana peeling machines increasingly use pneumatic actuation because it offers precision, cleanliness, and the ability to handle delicate fruits without causing damage. Pneumatic cylinders control gripping arms or peeling blades. This allows machines to adjust force and motion for consistent peel removal (Rahman & Islam, 2019). This method improves repeatability and reduces pulp wastage. This makes pneumatic systems especially suitable for small-scale or tabletop peeling devices.

Hydraulic systems, while less common in small-scale applications, work well for high-force operations and can handle larger fruits in industrial settings. They use fluid power to control peeling mechanisms, providing smooth, controllable movement. This reduces mechanical shocks that can bruise bananas (Deshpande & Kumbhar, 2018). Both pneumatic and hydraulic systems improve the efficiency and reliability of automated peeling machines. They offer scalable solutions for modern banana processing operations.

Fig 3 Hydraulic peeling machine
(Source: https://share.google/gNx5wwmJ1ftNg9izM)

D. *AI and Image – Guided Methods*

Recent developments in banana peeling have incorporated computer vision and artificial intelligence (AI) to improve accuracy and efficiency. Image-guided systems can detect banana size, orientation, and defects. This allows automated peelers to adjust motion and force dynamically (Zhu & Spachos, 2021). As a result, there is less fruit damage, more uniform peel removal, and better overall processing quality.

AI-assisted mechanisms improve efficiency by optimizing peeling paths and grading fruits at the same time. These systems are especially useful for industrial-scale operations, where high throughput and consistent product quality are necessary (Chen et al., 2024). By combining vision-based sensing and smart control, these mechanisms represent the future of precise banana processing, merging automation with flexible decision-making.

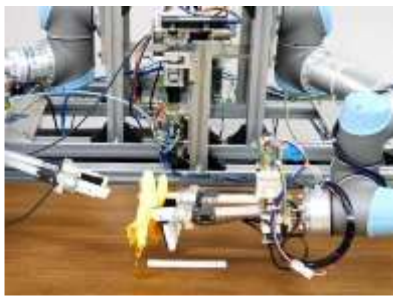

Fig .4 AI assisted peeling

(Source: https://share.google/8OAXSWgCJLdGZ7xmG)

III. PROPOSED METHODOLOGY

Bananas (Musa spp.) are placed individually on a feeding tray to ensure proper alignment and prevent overlap. The tray is made from food-grade materials to keep things clean and avoid contamination. A conveyor belt moves the bananas through the processing station at a steady speed. This setup allows for continuous operation and even exposure of each banana to the cutting and peeling tools, which cuts down on the need for manual handling. An infrared (IR) sensor detects each banana as it nears the cutting station. The sensor activates downstream mechanisms at the right moment to ensure accurate processing and prevent misalignment. A blade carefully cuts the top and bottom ends of the banana. This step ensures even peel removal and helps separate the peel from the pulp. The blades are made to use minimal force to lower the risk of bruising or damaging the pulp. A pneumatic actuator gently separates the peel from the banana pulp. The actuator uses controlled pressure and motion to completely remove the peel without crushing the fruit. The force and motion can be adjusted based on the banana's size, shape, or ripeness for better peeling efficiency. Peeled bananas are automatically discharged onto a collection tray or conveyor for further processing, such as slicing, chopping, or packaging. This reduces manual handling and maintains cleanliness. The design focuses on minimizing pulp damage, improving efficiency, and ensuring hygiene. It is suitable for small-scale industries, research projects, or tabletop setups. All components that touch the banana meet HACCP standards, ensuring safe food handling. The system is compact, energy-efficient, and easy to maintain.

IV. CONCLUSION

The proposed automated banana peeling system offers a compact, efficient, and fruit-friendly solution for small-scale and tabletop banana processing. It uses a conveyor-based feeding system, IR-sensor detection, cutting blades, and pneumatic actuators to ensure uniform peel removal with minimal damage to the fruit. The design lessens manual labor, speeds up processing, and maintains hygiene by using food-grade components. Overall, this project presents a practical, low-cost, and flexible solution for banana peeling. It has potential applications in small industries, research setups, and educational demonstrations.

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