# Some Investigations on Banana Peeling System

**Dr. A. Lovelin Jerald, Nagalakshmi S, Santhiya N**

**Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India**

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## ABSTRACT

Banana peeling is a primary operation in banana processing industries used for chips, flour, and other value-added products. Conventional manual peeling methods are labor- intensive, time-consuming, and unsuitable for continuous processing. To improve efficiency and hygiene, a tabletop banana peeling machine was designed and fabricated using air powered mechanism and sensor-based detection.

In the developed system, pre-trimmed bananas are placed on the adjustable base. When the sensor detects the material, it triggers the mechanical actuation. The peeling unit consisting of sharpened edges which removes the peel from the pulp.

This machine provides improved peeling efficiency, reduced manual handling, and better process hygiene. The compact and low-cost design makes the system suitable for small- and medium-scale banana processing units.

**Keywords:** Banana peeling machine, mechanical actuation, light sensor, Food processing equipment, Mechanical peeling, Post harvest processing, Automation in food processing, Low-cost processing unit

## INTRODUCTION

### Importance Of Banana Processing:

Banana processing helps to increase shelf life, improve market value, and reduce wastage of raw materials. Processed banana products such as chips and flour have high demand in food industries. Proper processing ensures uniform quality, better hygiene, and higher economic value. Efficient peeling and handling methods are required to maintain product quality during large-scale production.

### Post-Harvest Losses in Banana:

Banana is highly perishable and prone to mechanical damage during handling and processing. A significant amount of post-harvest loss occurs due to improper peeling, manual handling, and lack of suitable equipment. Traditional methods often result in damage to pulp, contamination, and wastage. Reducing post-harvest loss is important to improve efficiency and profitability in banana processing units.

### Need For Processing Equipment:

In many small-scale industries, banana peeling is still done manually, which requires more labour and time. Manual operations reduce productivity and increase processing cost. Integrated processing equipment is required to perform peeling quickly and hygienically. The use of mechanical systems and sensor-based detection can improve efficiency and provide continuous operation. Compact and low-cost machines are especially needed for small and medium food processing units.

### Limitations Of Existing Peeling Methods:

Manual peeling is slow, labor-intensive, and not suitable for continuous production. It may also cause injuries to workers and contamination of the product. Some available mechanical peelers are costly and complex, making them unsuitable for small-scale industries. Chemical peeling methods are not preferred due to safety and quality concerns. These limitations show the need for a simple, efficient, and hygienic peeling machine for banana processing.

**Objective Of the Present Study:**

The objective of the present study is to design and develop a tabletop banana peeling machine with Light sensor for automatic detection. The machine is intended to reduce manual labor, improve peeling efficiency, and maintain hygiene during processing. The developed equipment should be compact, low-cost, and suitable for small- and medium-scale banana processing industries while ensuring proper separation of peel and pulp.

## LITERATURE REVIEW

### 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).

### 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.

### Pneumatic and Hydraulic Methods

Modern banana peeling machines increasingly use mechanical actuation because it offers precision, cleanliness, and the ability to handle delicate fruits without causing damage. Mechanical 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 mechanical 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 mechanical and hydraulic systems improve the efficiency and reliability of automated peeling machines. They offer scalable solutions for modern banana processing operations.

**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.

**Research Gap**

Although significant advancements have been made in fruit peeling and food processing machinery, most existing studies focus on standalone operations rather than compact and integrated systems. Conventional banana peeling methods are largely manual or involve simple mechanical devices aimed at reducing labour, whereas advanced automated systems employ complex technologies such as robotics and image-guided control. However, these systems are predominantly designed for large-scale industrial applications and are not suitable for small-scale or domestic use.

There is a clear lack of research on the development of a tabletop banana peeling machine that integrates key functions such as feeding, peeling, and peel–pulp separation within a single compact unit. This limitation is particularly significant for small-scale processing units and household applications, where constraints related to space, cost, and operational simplicity restrict the adoption of existing technologies. Moreover, current low-cost machines often face challenges in achieving efficient peel separation and consistent performance, leading to product loss and reduced efficiency. The application of simple sensor-based automation in compact systems also remains limited. Therefore, there is a need to develop a compact, cost-effective, and efficient tabletop banana peeling machine that ensures continuous operation, hygienic processing, and ease of use, thereby addressing the requirements of small-scale and decentralized food processing applications.

**Scope of The Study**

The present study focuses on the design and development of a tabletop banana peeling machine suitable for small and medium scale food processing units The machine is intended to perform efficient peeling of bananas using a compact mechanical system integrated within a limited workspace. The design aims to minimize manual effort, improve processing efficiency, and ensure hygienic operation.

The developed system consists of a feeding section, compact peeling unit, and a simple mechanism for peel removal and separation. The study primarily emphasizes achieving uniform peeling with minimal pulp damage while maintaining ease of operation. The machine is designed using simple and cost-effective components to ensure affordability, portability, and low maintenance requirements.

This work is limited to the design, fabrication, and functional testing of the tabletop banana peeling mechanism under controlled conditions. It does not include advanced automation, large-scale industrial integration, or high-capacity continuous processing systems. However, the developed model can be further modified and scaled up for enhanced performance and capacity.

The proposed tabletop banana peeler is expected to provide a practical, economical, and user-friendly solution for small vendors, and micro-scale food processing units, thereby contributing to reduced labour dependency and improved processing efficiency.

## MATERIALS AND METHODOLOGY

### Design Considerations and System Overview

The tabletop banana peeling machine was designed to achieve efficient peeling with minimal pulp damage and reduced manual effort. The system is intended for snack food processing units with emphasis on compact size, low cost, and user-friendly operation.

The machine consists of an adjusting base for banana placement, peeling mechanism, light sensor, control unit, and collecting box. The use of a tabletop configuration ensures portability and space efficiency.

The design also considers hygienic operation, proper alignment of components, safety, ease of cleaning, and low maintenance, which are essential for food processing applications.

### Description of the Developed Machine

The developed tabletop banana peeling machine consists of a frame made of square mild steel tubes, a mechanical actuation, solenoid valve, Light sensor, control circuit, and peeling unit.

The mechanical system includes a compressor, 5/2 solenoid valve, polyurethane tubes, flow control valve, and mechanical actuation. The peeling mechanism is fabricated using sharpened edges mounted on an adjustable base to ensure proper positioning of the banana.

An electronic control circuit is used to regulate the operation of the Light sensor and mechanical actuation. The peeled banana pulp is collected separately in a container, while the peel is discharged at the bottom.

### Working Principle of the System

The working principle of the tabletop banana peeling machine is based on mechanical actuation controlled by an light sensor.

Initially, the top and bottom portions of the banana are manually trimmed and placed on the adjusting base. The compressor supplies compressed air to the solenoid valve, which directs the air into the mechanical actuation through polyurethane tubes.

When the Light sensor detects the presence of the banana, it sends a signal to the control circuit. The relay activates the solenoid valve, allowing compressed air to enter the mechanical actuation. The cylinder then produces reciprocating motion, driving the peeling mechanism.

The sharpened edges apply controlled pressure to remove the banana peel without causing significant damage to the pulp. The peeled pulp is collected separately, while the peel is discharged downward, ensuring hygienic and efficient operation.

### Materials Used and Fabrication Details

Mild steel square tubes (25 × 25 mm, 18 gauge) were used for constructing the frame due to their strength, durability, and cost-effectiveness. Additional materials such as flats, rods, and fasteners were used for structural support and assembly.

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The mechanical components include a 5/2 solenoid valve (230V), mechanical actuation, polyurethane tubes (6 mm), one-touch fittings, flow control valve, and dual exhaust system for improved airflow and efficiency.

The electronic system consists of a step-down transformer, full-wave rectifier, filter capacitor (1000 µF), voltage regulator (LM7805), Light sensor, LM358 comparator, BC547 transistor, and relay module for controlling the operation.

Fabrication processes involved cutting, welding, drilling, and assembly of all components. Proper alignment of the mechanical actuation, peeling mechanism, and base was ensured to achieve smooth operation and reduce vibration. The frame was coated with anti-corrosive paint to enhance durability and service life.

### Experimental Setup and Operating Conditions

The experimental setup was arranged to evaluate the performance of the developed tabletop banana peeling machine under laboratory conditions. Unripe bananas of nearly uniform size and maturity were selected for testing to ensure consistent results. Prior to feeding, the top and bottom ends of the bananas were manually trimmed to facilitate effective peeling.

The machine was placed on a stable, level surface, and all mechanical, mechanical, and electrical connections were checked before operation. The system was operated using a single-phase power supply for the control circuit, along with an air compressor to supply compressed air to the mechanical unit. Polyurethane tubes were connected between the compressor, solenoid valve, and mechanical actuation to ensure proper airflow and controlled actuation.

The light sensor was positioned near the adjusting base to detect the presence of the banana and initiate the peeling operation. During operation, the trimmed banana was manually placed on the adjusting base. Once detected by the Light sensor, a signal was sent to the control circuit, which activated the relay and solenoid valve.

The solenoid valve directed compressed air into the mechanical actuation, generating reciprocating motion. This motion drove the peeling mechanism consisting of sharpened edges, which applied controlled pressure to remove the banana Peel.

The peeled pulp was collected separately in a container, while the peel was discharged downward, ensuring hygienic handling. The performance of the machine was evaluated based on smooth operation, effective peeling, minimal pulp damage, and consistent functioning under repeated trials. The system was also observed for ease of operation and suitability for small-scale and domestic applications.

## RESULT AND DISCUSSION

The developed tabletop banana peeling machine was evaluated under controlled laboratory conditions to assess its performance in terms of peeling efficiency, processing time, throughput, and product quality. The results were compared with conventional manual peeling to highlight the advantages and limitations of the proposed system.

### Peeling Efficiency

The peeling efficiency was calculated as the ratio of completely peeled bananas to the total number of bananas processed. The machine achieved an average peeling efficiency of approximately 80% over repeated trials.

In comparison, manual peeling showed slightly higher efficiency (around 90-95%) due to human adaptability and precision. However, manual performance is inconsistent and highly dependent on operator skill, whereas the developed system provides more uniform operation.

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### Processing Time

The average time required for peeling a single banana using the developed machine was observed to be 6-8 seconds per fruit. In contrast, manual peeling required approximately 15-20 seconds per fruit, depending on the operator.

This indicates that the machine reduces processing time by nearly 50-60%, thereby significantly improving productivity.

### Throughput Capacity

Based on the processing time, the throughput of the system was estimated to be 7-10 bananas per minute. Manual peeling achieved approximately 3-4 bananas per minute under similar conditions.

Thus, the developed machine demonstrates nearly 2-3 times higher throughput, making it suitable for small-scale continuous processing applications.

### Pulp Damage Rate

Pulp damage was assessed through visual inspection after peeling. The machine exhibited a pulp damage rate of approximately 5-10%, mainly due to variations in banana size, shape, and the fixed configuration of the peeling edges.

Manual peeling resulted in slightly lower damage (around 5-8%), but with higher variability depending on operator handling. The observed damage in the machine is within acceptable limits considering the significant gain in processing speed and reduced labor requirement.

### Repeatability and Operational Consistency

The system demonstrated consistent and repeatable performance due to the integration of the light sensor and controlled mechanical actuation. Unlike manual peeling, which varies with operator fatigue and efficiency, the machine maintained a relatively uniform cycle time.

However, minor inconsistencies in peeling quality were observed when bananas of irregular geometry or varying maturity were processed, indicating limited adaptability of the current prototype.

### Comparative Analysis

| Parameter | Manual Peeling | Developed Machine |
|---|---|---|
| Peeling Time | 15-20 sec | 6-8 sec |
| Throughput | 3-4 bananas/min | 7-10 bananas/min |
| Efficiency | 90-95% | 80% |
| Pulp Damage | 5-8% | 5-10% |
| Labor Requirement | High | Low |

The comparison clearly shows that the developed system significantly enhances productivity and reduces manual effort, while maintaining acceptable peeling quality.

### Discussion on System Limitations

Despite improved performance, the system has certain limitations:

Occasional incomplete peeling due to fixed blade configuration

Sensitivity to variation in banana size, shape, and maturity

Slightly higher pulp damage compared to manual peeling

These limitations highlight the need for further optimization to improve adaptability and precision.

**Scope for Improvement**

Future improvements may include:

Adjustable or flexible peeling blades to accommodate size variation

Optimization of air pressure and actuation speed

Improved alignment and holding mechanism

Inclusion of statistical analysis with larger sample sizes

## CONCLUSION

A compact tabletop banana peeling machine was successfully developed and evaluated to address the limitations of conventional manual peeling. The system demonstrated an overall efficiency of approximately 80%, indicating its capability to perform banana peeling operations with reasonable consistency and reduced reliance on manual labor.

The machine exhibited improved processing uniformity and time efficiency compared to traditional methods. However, variations in peeling quality, including occasional incomplete peel removal and minor fruit damage, were observed. These limitations are primarily influenced by differences in raw material properties such as size, geometry, and maturity of the bananas.

The results suggest that the developed system has potential for application in small-scale and semi-commercial food processing environments, where cost, compactness, and ease of operation are critical factors. Further refinement in design and optimization of operating parameters is necessary to enhance performance and adaptability.

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