UNIABUJA Journal of Engineering and Technology

https://ujet.uniabuja.edu.ng/

ISSN: 2714-3236 (Online); 2714-3228 (Print)

Volume 2, Issue 1, 2025; 217-223

Development of an Automated Potato Peeling Machine with Remote Control Capability

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Abstract
Millions of people worldwide rely heavily on potatoes, a herbaceous, incalescent groveling plant, as a source of carbohydrates. Traditionally, a hand knife is used to physically peel potatoes. In addition to being labour-intensive and time-consuming, traditional peeling techniques produce a lot of waste since they remove edible sections unevenly and excessively. To address these shortcomings, this work develops an automated potato peeling machine with remote control capability. The design comprises a 12V DC power supply that interfaces the mains power with the machines control panel. The buck converter that steps down the voltage from the 12 Volt DC power source to a lower and steady level needed by other components. The ESP32 microcontroller with integrated Bluetooth and Wi-Fi controls the DC motor through the Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET). Torque generated by the DC motor is then transmitted to the shaft which turns the peeling drum for the peeling process. The results of the test carried out on the developed machine shows that; for 0.5kg of potato tubers, the peeling efficiency was 92%, for 1kg, 90%, for 1.5kg, 89%, for 2kg, 86% and for 2.5kg, 80%. It recorded an average peeling efficiency of 87% and reduced peeling loss of 7%. Usage of the developed machine has improved potato peeling efficiency and reduced post-harvest losses due to peeling.

Keywords: *Peeling machine, remote control, potato, microcontroller, automation.*

1.0 Introduction

Potatoes and other herbaceous plants are a major source of carbohydrates for millions of people worldwide, particularly in developing countries. (Amagloh et al., 2022). Their tuberous roots are high in calcium, iron, and vitamins A and C and they contain about 27% carbs (Taiyeba, Gupta & Verma, 2020; Rezvanian, Jafarinejad & Bovell-Benjamin, 2023). Darker-coloured types are particularly high in dietary fibre, vitamins C, B2, B6, E, and biotin as well as carotenes, which are precursors to vitamin A (Amagloh et al., 2021; Kumar et al., 2023; George et al., 2023). About 20% of potatoes are dry matter and 80% are water (Dewada, Ranawat, Deora, 2018; Samsher et al., 2020).

Starch makes up a significant amount of the dry substance. On a fresh weight basis, the starch content is approximately 14% and the sugar content is approximately 2% (Tolessa, 2018, Singh, Raigond, Kharumnuid, 2020). Potatoes have a crude protein level of 2% and a fat content of 0.1%. Due to its many health advantages and nutritional value, such as their anti-inflammatory, anti-cancer, anti-diabetic, anti-microbial and antioxidant properties, potatoes are often referred to as superfood. They are also a rich source of minerals and physiologically active chemicals (Islam, 2024; Gelaye, 2024). As a result of their high nutrient content, potatoes are used in the fight against malnutrition, especially in areas where dietary shortages are common (Neela & Fanta, 2019).

The edible tuberous roots of the crop are extremely perishable, lasting no more than five weeks in normal storage circumstances and only two weeks in tropical areas. Significant post-harvest losses result from this high perishability, obstructing initiatives to increase food security and farmers' financial gains. Ineffective post-harvest processing, especially during the peeling stage, is one of the primary causes of this loss (Gaudino et al., 2020; Akter et al., 2022). An essential step in potato processing is peeling (Shinde et al., 2018), that is, when potatoes are needed for consumption or for processing into finished product like chips and crisps, they are peeled. It is an essential first step in the preparation of potato tubers. Traditionally, a hand knife is used to physically peel potatoes. In addition to being labour-intensive and time-consuming, traditional peeling techniques produce a lot of waste since they remove edible sections unevenly and excessively (Oyedele, Kilanko & Leramo, 2019; Damayanti, Prayogi & Basukesti, 2021, Shruthi 2022).

The quality of processed potatoes can be improved, the peeling losses reduced and overall production can be increased by introducing an effective peeling machine (Zhou et al., 2022). Since potatoes vary greatly

Received: 30-01-2025 / Accepted: 18-03-2025 /Published: 31-03-2025

in size, shape, and skin texture, it is necessary to understand their unique geometrical and mechanical properties in order to develop a peeling machine that is specific to their needs while minimizing damage to the tubers (Vithu, Dash & Rayaguru, 2019). The machine must also be sturdy, dependable and able to function in a variety of environmental settings. Because sweet potatoes have special geometrical and mechanical characteristics, existing peeling machines made for other tubers frequently don't work well with them. These machines' main issue is their size, which makes it challenging to move and use them in smaller farming settings (Talodhikar, Gorantiwar & Dhole, 2017). Potatoes' potential as a staple food and industrial raw material is limited by the lack of an effective, dependable and reasonably priced peeling solution that tackles these issues (Fouda, Darwesh, & Elkhodarey, 2019). Consequently, there is an urgent need to develop a potato peeling machine that is portable for use at home or by small-scale farmers, with automated operation and remote-control capability, to minimize peeling loss and maximize efficiency. The machine would assist food security and economic growth in areas where potatoes are a staple crop by improving the peeling process and the entire potato value chain, from farm to table (Abong *et al*., 2016).

Therefore, the objective of this work is to develop a portable potato peeling machine with remote control capability to minimize post-harvest losses due to peeling.

Considerable progress has been made in developing potato peeling machine. A high-capacity potato peeling machine that can process 400 kg of potatoes per hour was introduced by Tyagi *et al*, (2018). This machine was designed for the Ludhiana, India, a commercial production setting. Its peeling drum, which has protrusions on the interior, rotates and uses abrasion to remove the peel from potatoes. The work addressed the demand for scalable solutions in potato processing by automating the peeling process. The ability of their machine to continue operating at a high level of efficiency shows how automation may greatly increase output in large-scale enterprises. Its size and capacity, however, would make it unsuitable for small-scale farmers, suggesting the need for compact and more effective solutions. A semi-automatic potato peeler was introduced by Zin *et al*., (2021) with the goal of accelerating the manufacturing of French fries. The device used a dc motor to drive abrasive and rotating motion mechanisms inside a vertically oriented drum. This design's simplicity was intended to speed up the peeling process, but it also sparked worries about requirement for regular maintenance. A small-scale, automated sweet potato peeling machine was fabricated by Kumar (2019) with an emphasis on small-scale farmers' ease of use. The machine was made to be small and portable, and it included an abrasive peeling mechanism. Even with its creative design, the machine had trouble peeling sweet potatoes with irregular shapes and suffered from moderate peeling losses, indicating that it needs to be improved for handling different tuber geometries. This study emphasizes how crucial it is to create devices that are both effective and flexible enough to accommodate the wide range of sweet potato shapes and sizes.

This research effort advances knowledge by the development of a potato peeling machine with remote control capability for post-harvest losses reduction and enhanced efficiency.

2.0 Materials and Methods

The potato peeling machine is designed to carry out an effective peeling through optimal power management and component control. A 12V DC power supply, which transforms alternating current (AC) from the mains into direct current (DC), is essential to its operation. The machine's safe and effective operation depends on its capacity to convert, control, and stabilize voltage. Stepping down the voltage from the 12 Volt DC power source to a lower, steady level needed for other components is a crucial function of the buck converter. The actuator that transforms electrical energy into mechanical motion is a DC motor. Following instructions from the microprocessor, the Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) controls its speed while the potentiometer regulates it. The ESP32 microcontroller, which includes integrated Bluetooth and Wi-Fi, is the central component of the control system. By controlling the motor's speed and direction using preprogrammed logic, the microcontroller enables programmable circuit control. The microcontroller's incorporation improves the machine's usefulness by enabling remote operation, which is in line with current trends toward agricultural equipment that is smarter and easier to use. By modifying the voltage in response to inputs from the microcontroller, MOSFET acts as a switch for the DC motor, regulating its power and speed. The machine can be operated with a smartphone because to its remote-control capabilities via a locally hosted web interface. Figure 1 displays the block diagram for the system.

To guarantee durability and functionality, the materials used in the development of the potato peeling machine prototype were carefully chosen. Because of its exceptional strength, light weight and corrosion resistance, light aluminum roofing sheet was chosen for the fixed abrasive drum. Because the spinning base needs to be able to sustain mechanical stress while in use, steel was chosen for the drum's base to ensure stiffness and wear resistance. The raw materials were trimmed to the proper sizes and shapes throughout theproduction process. To guarantee a proper fit and finish, surfaces were smoothed and finished through grinding. Drilling was done to make holes for mounting components and welding was used to fuse metal components together to form a sturdy and solid framework. The circuit schematic in Figure 2 shows the component layout. Coding, using 'C' programming, that guarantees smooth connection between the hardware and the software was used in the programming for the automation and control of the peeling process. The programming improves the machine's efficiency and usability by enabling remote control features. Figure 3 shows the machine's dimensions, broken down into individual parts.

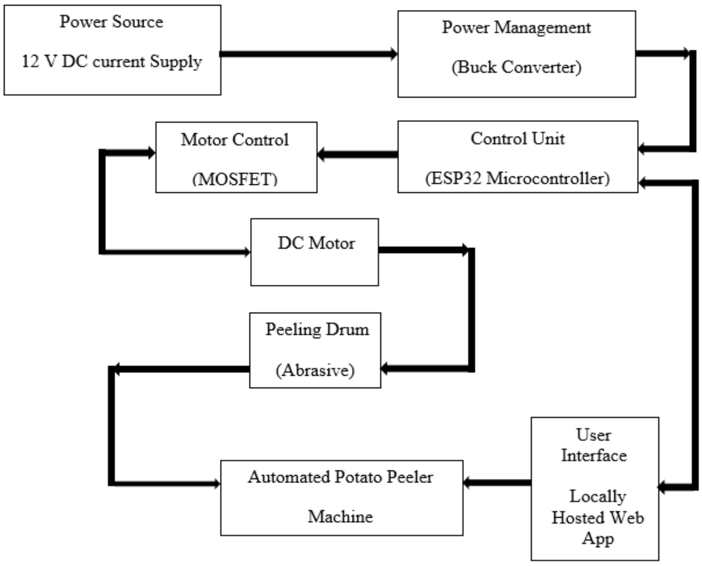

Figure 1: *Block diagram of the potato peeling machine*

Design Calculation

The power requirement and the needed torque for the smooth operation of the peeling machine is shown in Table 1.

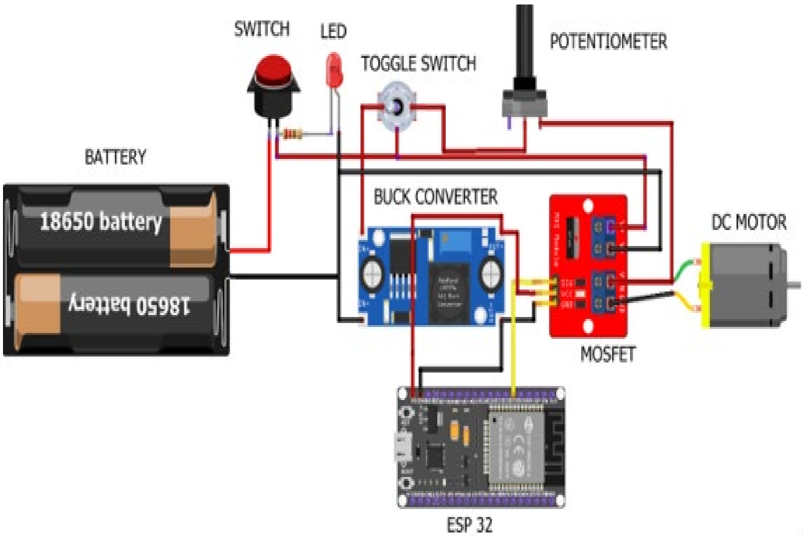

Figure 2: *Potato peeling machine circuit diagram*

Table 1: Ratings of electronic components

Device	Operating voltage (V)	Current (I)	Power (I x V)
DC motor	12	7.5	90
ESP32 Microcontroller	3.6	0.5	1.8
Buck converter	12	5	60
Total power drawn from the main power supply			=

The Dc motor torque was calculated using equation 1.

$$\text{DC motor torque, } T = \frac{60P}{2\pi N} \quad 1$$

Received: 30-01-2025 / Accepted: 18-03-2025 / Published: 31-03-2025

$$= \frac{60 \times 90}{2 \times 3.142 \times 60} = 14.3\text{Nm}$$

where:
P = power
N = speed

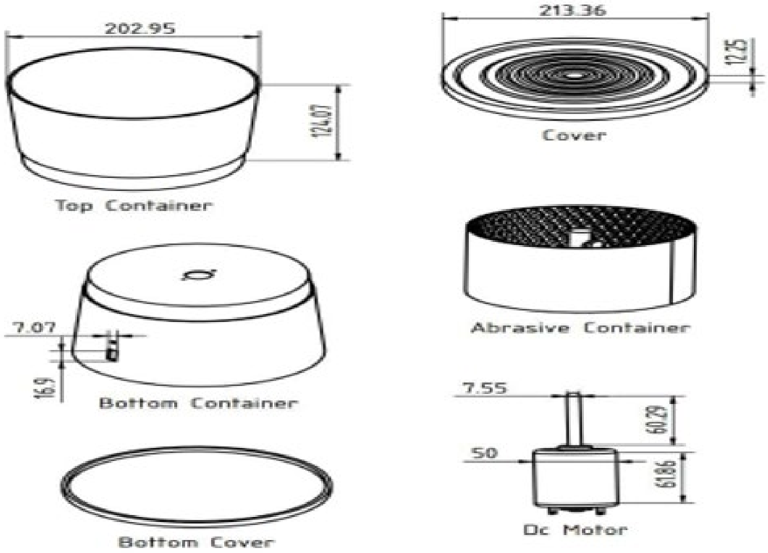

Figure 3: *Potato peeling machine dimension*

The power required for the operation of the 3 kg capacity machine is 160 W. Torque of 14.3 Nm is transmitted to the shaft which turns the aluminium abrasive installed on it. Figures 4 and 5 depict the aluminium abrasive and the built prototype.

Figure 4: *Aluminium abrasive*

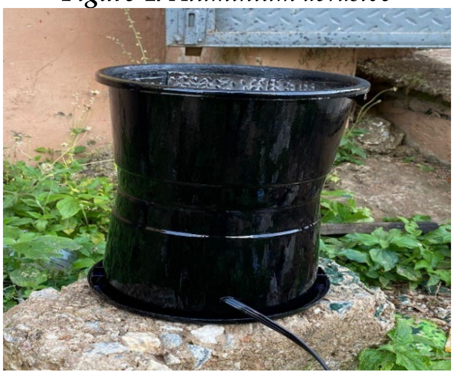

Figure 5: *Constructed prototype*

The peeling efficiency of the machine, based on the, 0.5kg, 1kg, 1.5kg, 2kg and 2.5kg specimen peeled was determined using equation 2.

$$\eta_{\text{peeling}} = \frac{W_{\text{peeled}}}{W_{\text{unpeeled}}} \times 100 \qquad 2$$

This was done to measure how effectively the machine removes the peel from the potato tubers.

Received: 30-01-2025 / Accepted: 18-03-2025 /Published: 31-03-2025

3.0 Results and Discussion

A straightforward procedure is used to realize the peeling process. By stepping down the voltage from the 12V DC power supply to the precise voltage needed by the machine's electronic components, the buck converter regulates the voltage provided to the individual components when the peeling machine is turned on. A web application hosted on a local server allows the user to communicate with the system. A user-friendly interface for remote operation and monitoring is offered by this web application. The user's device, such as an Android phone, connects to the local network, which connects to a microcontroller with Bluetooth and Wi-Fi, in order to access the web application. The microcontroller turns on and controls the peeling drum and DC motor in response to commands from the web application. By adjusting the motor's speed and direction in response to user input, the peeling process may be precisely controlled. Then, to make peeling the potatoes easier, the peeling drum revolves. The machine's output shown in Figure 6 indicates it operated efficiently.

Figure 6: *Potato before and after peeling using machine*

The result of the comparison of the weight of the potatoes peeled using the developed machine with the weight of the potatoes peeled manually is shown in Table 2.

Table 2: Weight comparison

Mass (kg)	Weight of potatoes (kg) (Machine-peeled)	Weight of potatoes (kg) (Manually-peeled)	Weight difference
0.5	0.46	0.41	0.05
1.0	0.90	0.84	0.06
1.5	1.34	1.26	0.08
2.0	1.72	1.59	0.13
2.5	2.00	1.82	0.18

According to Table 2, loss of 10%, 6%, 5%, 7% and 7% of the various masses of the potatoes peeled was prevented as a result of the usage of the developed potato peeling machine. Meanwhile, irregularity associated with manual peeling was responsible for the noticeable flesh loss in manually-peeled potatoes. The result of the peeling efficiency of the machine, computed using equation 2, is shown in Table 3.

Table 3: Peeling efficiency (Machine-peeled)

Mass (kg)	Peeling Efficiency
0.5	92
1.0	90
1.5	89
2.0	86
2.5	80
Average	87

As shown in Table 3, the machine has the highest efficiency when there were few potatoes in the peeling drum. The lowest efficiency was recorded when the drum was filled with potato tubers while the average efficiency of 87% shows that the machine is effective. Table 4 shows the result of the peeling efficiency of the sample of the manually peeled specimens shown in Figure 7.

Figure 7: *Potato before and after manual peeling*

Table 4: Peeling efficiency (Manually-peeled)

Mass (kg)	Peeling Efficiency
0.5	82
1.0	84
1.5	84
2.0	80
2.5	73
Average	80

As shown in Table 4, the efficiency of the manual peeling method is low because a considerable potato flesh was lost during the manual peeling process. Usage of the developed machine has improved potato peeling efficiency and reduced post-harvest losses due to peeling.

4.0 Conclusion

This work developed an automated potato peeling machine with remote control capability. The design comprises a 12V DC power supply that interfaces the mains power with the machines control panel. The buck converter that steps down the voltage from the 12 Volt DC power source to a lower and steady level needed by other components. The ESP32 microcontroller with integrated Bluetooth and Wi-Fi controls the DC motor through the Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET). Torque generated by the DC motor is then transmitted to the shaft which turns the aluminium abrasive for the peeling process. The outcome of the test carried out on the developed machine shows that; for 0.5kg of potato tubers, the peeling efficiency was 92%, for 1kg, 90%, for 1.5kg, 89%, for 2kg, 86% and for 2.5kg, 80%. It recorded an average peeling efficiency of 87%. Usage of the developed machine has improved potato peeling efficiency and reduced post-harvest losses due to peeling.

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Received: 30-01-2025 / Accepted: 18-03-2025 /Published: 31-03-2025

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