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Development and Performance Evaluation of Potato *(Solanum tuberosum)* Peeling Machine

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Abstract:

Mechanization of post-harvest operations has become essential for improving processing efficiency, reducing labor dependency, and ensuring uniform product quality in the food processing sector. In particular, the potato processing industry requires efficient and cost-effective solutions to address challenges associated with manual peeling, including time consumption, inconsistency, and high labor costs. In this context, the Department of Processing and Food Engineering, MCAET, Ambedkar Nagar, Uttar Pradesh, undertook the design, development, and performance evaluation of a potato peeling machine utilizing locally available potato varieties. The prototype was engineered using computer-aided design (CAD) techniques and operates on the principle of abrasive friction. Fresh potatoes are introduced into a rotating peeling drum, where peel removal is achieved through interaction with a roughened internal surface designed to enhance frictional forces. Performance evaluation demonstrated notable operational efficiency. The machine achieved a peeling efficiency of 96.1% while processing a 12 kg batch within 3 minutes, corresponding to a throughput capacity of approximately 240 kg/h. These results indicate a significant improvement in processing efficiency along with a considerable reduction in manual labor requirements. Economic feasibility was assessed using standard financial indicators, including cost–benefit ratio, payback period, and break-even point. The analysis revealed a high cost–benefit ratio of 18.49, indicating strong economic viability. Additionally, the system exhibited a rapid payback period of approximately 20 days and a low break-even threshold of 614.10 kg, further reinforcing its financial feasibility.

Overall, the developed potato peeling machine demonstrates both technical effectiveness and economic sustainability. The study highlights its potential as a practical and scalable solution for enhancing productivity and profitability in the potato processing industry.

Keywords: Potato peeling machine; Abrasive peeling; Peeling efficiency; Throughput capacity; Economic analysis; Cost–benefit ratio; Payback period; Break-even point.

INTRODUCTION

Root and tuber crops, including potato (*Solanum Tuberosum L.*), carrot (*Daucus Carota L.*), beetroot (*Beta vulgaris L.*) and arbi (*Colocasia Esculenta L.*), are widely grown and consumed as staple foods in many parts of India. According to FAO, roots and tubers account for 9 % of the total cultivated area for primary crops in India **(Anon., 2024a*)***. The quantity and quality of the protein in root and tuber crops are variable and relatively low. The advantages of root and tuber crops as staple foods include the following: they are well adapted to diverse soil and environmental conditions and a wide variety of farming systems; they are highly efficient edible sources of carbohydrates when compared to other food crops **(Fadeyibi and Ajao, 2020).**

Potato (*Solanum tuberosum* L.), popularly known as the "King of Vegetables," has emerged as the fourth most important food crop in India after rice, wheat, and maize **(Pandey et al., 2008; Food and Agriculture Organization, 2023).** The Indian vegetable basket is incomplete without potato due to its wide adaptability and high productivity. The high dry matter, edible energy, and protein content make potato a nutritionally superior vegetable as well as a staple food not only in India but also worldwide **(Khurana & Naik, 2003).** It has now become an essential part of breakfast, lunch, and dinner across the globe. Being a short duration crop, it produces more quantity of dry matter, edible energy and edible protein in less duration of time than cereals like rice and wheat. Hence, potato may prove to be a useful tool to achieve the nutritional security of the nation **(Anon., 2024b)**. At the time of inception of ICAR-CPRI, in the year 1949, India used to produce 1.54 million tons of potatoes from 0.234 million ha area at an average productivity level of 6.58 t/ha. As per FAOSTAT, the potato production in India during 2013 was 45.34 million tons from 1.99 million ha area with a productivity of 22.76 t/ha. There has been a phenomenal increase in potato area (8.5 times), production (29.4 times) and productivity (3.5 times) over six decades **(Anon., 2024c)**.

With advancements in technology, alternative peeling techniques are being explored to overcome the limitations of traditional abrasive systems. Infrared (IR) peeling has emerged as a promising method that uses rapid surface heating to loosen the potato skin. According to **Li et al. (2023),** IR peeling offers improved energy efficiency and reduced environmental impact compared to conventional methods. Similarly, waterjet peeling technology has gained attention due to its ability to minimize flesh loss and improve peeling precision. A recent study by **Shi et al. (2025)** demonstrated that optimized waterjet systems can significantly enhance peeling quality while maintaining high efficiency.

Research on similar tuber crops also provides useful insights for potato peeling machine development. **Zhang et al. (2023)** developed a combined peeling machine and found that parameters such as shaft speed, feed rate, and processing time significantly affect peeling efficiency and product quality. Additionally, **Nagar et al. (2025)** reported that optimizing machine parameters can reduce mechanical damage while improving peeling performance in tuber crops.Despite these advancements, there remains a need for cost-effective, compact, and easy-to-fabricate peeling machines suitable for small-scale industries and rural applications. Advanced technologies such as infrared, chemical, and waterjet peeling, although efficient, are often expensive and complex, limiting their adoption in developing regions **(Jerald et al., 2022; Neupane et al., 2025; Singh et al., 2023)**. Therefore, the development of a low-cost potato peeling machine using CAD-based design, appropriate fabrication techniques, and systematic performance evaluation is still highly relevant, particularly for improving efficiency and reducing labor dependency in small-scale processing units **(Suleiman, 2022).**

MATERIALS AND METHODS

In this research work, the potato was collected from the local market of the Ambedkar Nagar district for the testing and performance evaluation of the potato peeling machine. The potato variety Kufri Badshah and Kufri Ashoka which is widely grown in Ambedkar Nagar district was selected for the study. In the current study, the size of the potato was assessed to design the roller and peeling mechanism of the peeling machine. The spatial dimensions of the potato were determined using a vernier calliper, shape of the potato was used to design the drum and peeling mechanism of potato **(Verma et al., 2024)**. The details of the used instrument are depicted in table 1.

Table 1 Details of instrument used to determine physical properties of potato

S. No	Name of instrument	Description	Range	Accuracy
1.	**Vernier caliper**	To measure the diameter of potato	0 – 200 mm	0.02 mm
2.	**Electronic Weighing Balance**	To weigh the potato	0.01 - 10 kg	0.5 gm

Development of Potato peeling machine: A potato peeling machine was designed and developed for small-scale processing units. The machine mainly consists of a main frame, abrasive drum, shaft, handle, gear system, and supporting components such as bearings and housing. The frame is constructed to provide proper support and stability to all machine elements during operation. The machine is hand-operated, and power is transmitted manually through a handle connected to a gear system. The gear mechanism helps in transmitting motion and maintaining suitable rotational speed of the peeling drum. The peeling unit consists of a rotating drum with an abrasive inner surface made using 24-grade grit bonded with epoxy. Fresh potatoes are fed into the drum, and as the drum rotates, the abrasive surface removes the peel through friction. Water is supplied through a pipe during operation to assist in washing and improving peeling efficiency.

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Table 2 Specification of fabricated Potato peeling machine

S. No.	Components	Dimensions	Description	Fabricated/Selected
1.	Main frame	Length = 640 mm Width = 760 mm Height = 792mm	Supporting structure on which all the parts of the machine are assembled.	Fabricated
2.	Peeling drum	Length = 609.6 mm Outer diameter = 487.68 mm Thickness = 3 mm	It provides friction which helps in peeling of tuber crops.	Fabricated
3.	Hollow shaft	Inner diameter = 19 mm Outer diameter = 29 mm	To provide the free rotation to the peeling drum and helpful in water supply into the peeling drum.	Fabricated
4.	Gear shaft	Diameter = 29 mm	To provide the direct power to the drum with the help of handle.	Fabricated
5.	Pillow block bearing	Bore diameter = 29 mm	Gear and hollow shaft passed through it and received smooth rotation from it.	Selected
6.	Sieve	Length = 760 mm Width = 865 mm Thickness = 1 mm	It collects the peeled product and helps out the drainage system.	Selected
7.	Handle	Length = 145 mm Width = 160 mm	It provides the power to the peeling drum.	Fabricated
8.	Water tank	Height = 250 mm Length = 100 mm	It fulfils the water requirement.	Fabricated

Performance Evaluation of Potato peeling machine

For conducting experiment, the machine parameters i.e. weight of potato and time taken as variable parameters whereas peeling efficiency (%) and throughput capacity (kg/h) taken as dependent variable. The experimental design for the performance evaluation of the Potato peeling machine.

Table 3 illustrates the research plan in brief for achieving the objective of this research

Table 3 Experimental design for performance evaluation of the Potato peeling machine

Parameter	Variables	Replication
Independent	**Levels**	
Weight of potato	4 kg	05
	8 kg	
	12 kg	
Time taken	2 min	05
	3 min	
	4 min	
Dependent		
Peeling efficiency (%)	-	
Throughput capacity(kg/h)	-	

Peeling efficiency: The peeling efficiency of potato was calculated as a percentage of the mass collected through the peeler outlet to the total mass of peel (Kosgollegedara et al., 2021).

$$Peeling\ efficiency\ (\eta) = \frac{M_{po}}{(M_{po} + M_{pr})} \times 100$$

Where, Mpo is the mass of peel collected through the peel outlet of the machine (kg) and Mpr is the mass of peel removed by hand after machine peeling (kg).

Theoretical peeling capacity: The average time taken to peel one kilogram of food sample without considering time wastage was used to determine the theoretical peeling capacity. Following equation was used to calculate the theoretical peeling capacity **(Kosgollegedara et al., 2021).**

$$Theoretical\ peeling\ capacity = \frac{\left(\frac{60min}{h}\right)}{time\ taken\ to\ peeled\ 1\ kg\ of\ food\ material\ (min/}$$

Techno Economic Feasibility of the Potato Peeling Machine: Most of the people are interested in knowing whether the machine will be profitable or not. During introducing the new technology, the cost analysis is very important for a new developed technology; operating cost of the machine is total of fixed cost and variable cost of the machine. The total cost of the multi-tuber peeling machine was determined by knowing the cost of the material and fabricating cost of the multi-tuber peeling machine. The operational cost (Rs/year) was used. The techno economic feasibility of the machine was calculated using straight line method of depreciation estimation. The techno economic calculation of the machine was done by following steps; **(Singh et al., 2023)**

Statistical analysis: The statistical analysis of the data was done using the software SPSS. The data of the machine is optimized using the randomly block design (RBD).

RESULT AND DISCUSSION

The physical properties of the tuber helped in developing the Potato peeling machine because by knowing the dimensions of the tuber we were able to make the peeling drum so that they can adopt the different size and shape of tuber and to peel it. Table 4.1 shows the various dimensions of the tuber found in Ambedkar Nagar district near to the college campus, MCAET are as follows:

Table 4 Physical properties of locally available potato

S. No.	Properties	Potato
1.	Length of Potato	50 – 60 mm
2.	Weight of Potato	150 gm

A 3-D CAD view and actual view of developed prototype of Potato peeling machine is shown in Fig.1. The major components of this machine are namely handle, main frame, peeling drum, shaft, gear, and pillow block bearing. The machine requires one labour to operate this machine. When the peeling operation of tuber crops will complete the operator will collect the peeled tuber crops at the end of the machine.

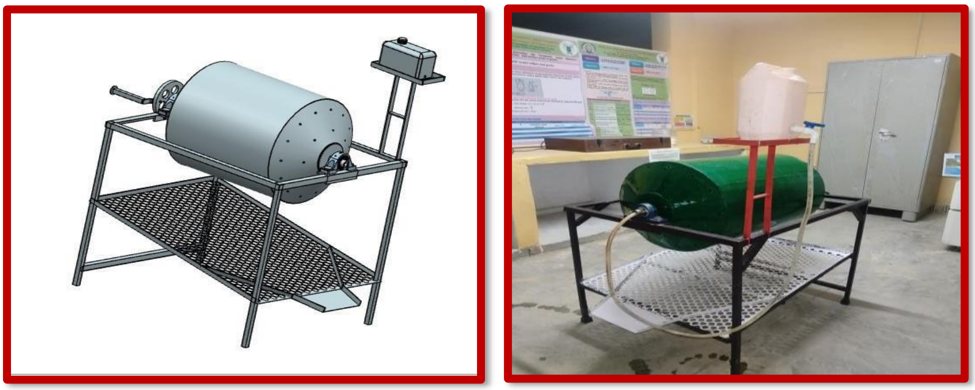

Fig. 1 (a) 3-D CAD view of Potato peeling machine, (b) Actual view of Potato peeling machine

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Table 5 Effect of peeling time and weight of potato on peeling efficiency and throughout capacity

Weight of potato	Peeling efficiency (%)				Throughout capacity (kg/h)			
	2min	3min	4min	Mean	2min	3min	4min	Mean
T1 (4 kg)	82.28	87.69	92.82	87.59	114.30	76.01	56.39	82.33
T2 (8kg)	92.96	89.78	94.86	92.53	232.44	155.72	116.13	168.09
T3 (12kg)	95.62	94.54	98.10	96.08	345.06	228.44	168.45	247.31
Mean	90.05	90.67	95.26		230.06	153.39	113.65	

Peeling Efficiency: Fig. 2 illustrates that the peeling efficiency of the machine varied between 83.33 to 98.03 %.

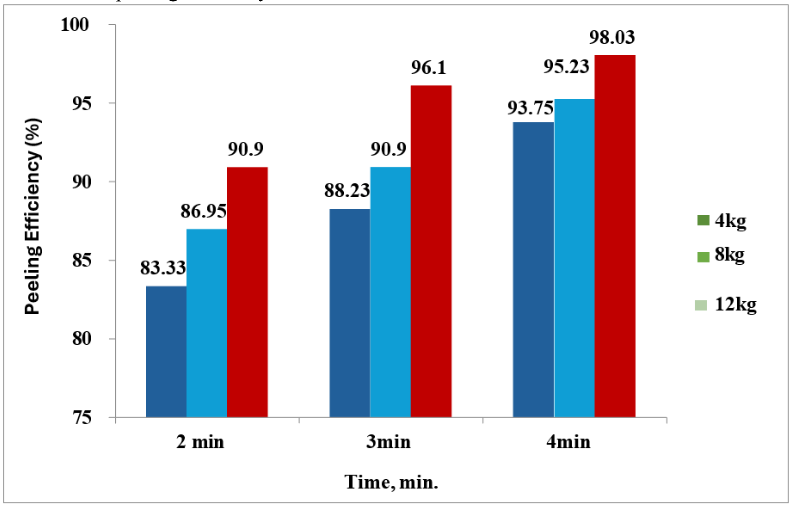

Fig. 2 Relationship between peeling efficiency and time at various level of weight of potato

The maximum peeling efficiency was 98.03 % was obtained at 12 kg weight of batch and time 4 min while the minimum peeling efficiency 83.33 % was found at 4 kg weight of batch and time 2 min. It was also observed that when the weight of the potato was taken below the 4 kg, the peeling efficiency decreases.

Throughput Capacity : The throughout capacity of the machine varied between 60 kg/h to 360 kg/h. The minimum throughout capacity i.e. 60 kg/h was found at 4 min time taken peeling process of potato whereas the maximum throughput capacity i.e. 360 kg/h was found at 2 min time taken peeling process of potato. From the results, it was clear that as the weight of potato increases the throughput capacity of the machine increases whereas decreasing in weight of potato decreases the throughput capacity. From Table 5 it was also clear that as the weight of potato decreases, the throughput capacity of the machine decreases and further decreasing the speed of peeling drum the throughput capacity of the machine also decreases.

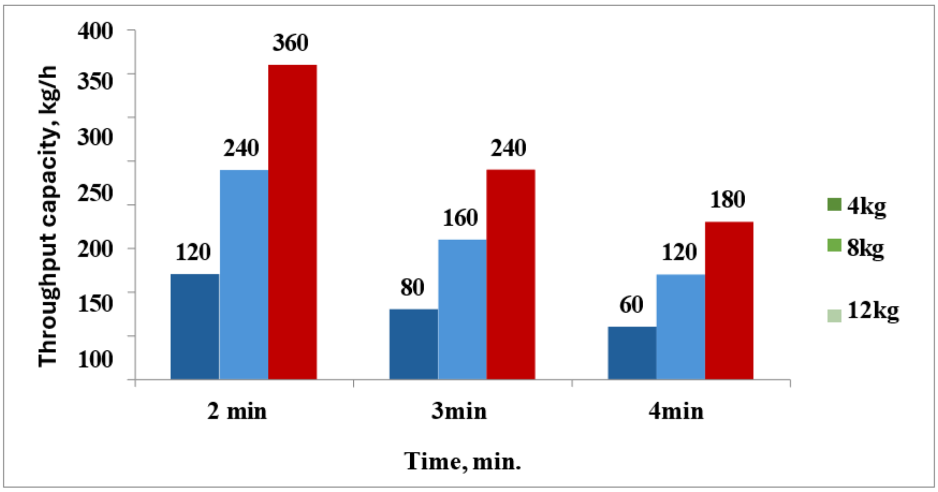

Fig. 3 Relationship between throughout capacity and time at various level of weight of potato

Effect of independent parameter on peeling efficiency: From Table 6, it is clearly shown that there is a significant effect of weight of potato, time taken and comprehensive effect (weight of potato × time taken) on peeling efficiency (%) at 5 % level of the significant the p value of all dependent parameter of less than 0.001 was observed.

Table 6 ANOVA table for effect of independent variables on peeling efficiency

Source of variation	SS	df	MS	F	P-value	F crit
Sample	590.1424	2	295.0712	81.02238	<0.001	3.259446
Columns	215.0009	2	107.5004	29.5181	<0.001	3.259446
Interaction	149.6132	4	37.40329	10.27042	<0.001	2.633532
Within	131.1065	36	3.641848			
Total	1085.863	44				

Effect of independent parameter on thorough put capacity: From the Table 7, it is clearly shown that there is a significant effect of weight of potato, time taken and comprehensive effect (weight of potato × time taken) on throughout at 5 % level of the significant the p value of all dependent parameter of less than 0.001 was observed.

Table 7 ANOVA table for effect of independent variables on throughout capacity

Source of Variation	SS	df	MS	F	P- value	F crit
Sample	204499.1	2	102249.6	38193.63	<0.001	3.259446
Columns	106078.6	2	53039.29	19811.95	<0.001	3.259446
Interaction	18214.54	4	4553.636	1700.935	<0.001	2.633532
Within	96.37692	36	2.677137			
Total	328888.6	44				

Techno Economic Feasibility of the Potato Peeling Machine: The materials needed to build the machine were sourced from the local market Most of the machine's components were designed and manufactured in the workshop of the Department of Processing and Food Engineering at MCAET, Akbarpur

(Ambedkar Nagar). The techno-economic feasibility of the machine was assessed using the straight-line method for depreciation estimation. Table 8 provides details of the cost economic analysis of the potato peeling machine **(Verma et al., 2024).**

Table 8 Techno economic analysis of Potato peeling machine

S. No.	Description	Unit	Potato peeling machine
			Value (inc. GST)
1.	**Cost of machine**	**Rs**	15300/-
I.	Life in year	**Year**	10
II.	Depreciation	Rs/Year	1377/-
III.	Total interest	Rs/Year	841.5/-
IV.	Housing tax	Rs/Year	459/-
1.	**Total fixed cost**	Rs/Year	2677.5/-
a)	Maintenance/year	Rs/Year	765/-
b)	Total working days per year	Rs	365
c)	Total working hours per year	Rs	500
d)	labour charges	Rs/Day	400
2.	**Variable Cost**		25765/-
3.	**Total operational Cost Per Year**	**Rs**	28442/-
4.	**Total operational cost**	**Rs/h**	**50/-**
5.	**Capacity of the peeling machine**	**Kg/h**	**240**
6.	**Machine productivity per year**	**Kg/year**	**120000kg**
7.	**Cost of peeling by machine**	**Rs/kg**	**0.237**
8.	**Capacity of peeling by manual method**	**Kg/day**	**400**
9.	**Saving/ Profit**		**4.383**
10.	**Benefit-cost ratio**		**18.49**
11.	**Payback period**		**19.46 days**
12.	**Breakeven point**	**kg**	**642.2kg**

CONCLUSION

This study focused on the development and performance evaluation of an abrasive-type potato peeling machine. The machine was designed using NX software and fabricated using low-cost, locally available materials.

The performance results showed that operating parameters such as peeling time and batch size significantly affected efficiency and capacity. The optimum condition was obtained at a 12 kg batch and 3 minutes of peeling time, achieving a maximum peeling efficiency of 96.1% and throughput capacity of 240 kg/h. The minimum efficiency (90.9%) was recorded at 2 minutes, while the lowest throughput (180 kg/h) occurred at 4 minutes.

Economic analysis indicated that the machine is highly viable, with a cost–benefit ratio of 18.49, a payback period of approximately 20 days, and a break-even point of 614.10 kg. Overall, the developed potato peeling machine is efficient, economical, and suitable for small- to medium-scale processing operations.

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