

# ENHANCING PEELING EFFICIENCY IN GINGER PROCESSING: A MODIFIED MECHANICAL APPROACH

## POBOLJŠAVANJE EFIKASNOSTI LUŠTENJA U PRERADI ĐUMBIRA: MODIFIKOVANI MEHANIČKI PRISTUP

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### ABSTRACT

The growing demand for ginger in food, pharmaceutical, and cosmetic industries has exposed the limitations of manual peeling, which is labor-intensive, time-consuming, and prone to product loss. This study presents the design, fabrication, and evaluation of a locally sourced ginger peeling machine for small-to-medium scale processors. The machine was constructed using 3 mm angle iron for the frame and a galvanized steel drum (Ø410 mm × 430 mm, thickness 1.5 mm) as the peeling chamber. A 6 hp prime mover operating at 2400 rpm provided power through a bevel gear (1:1) and pulley system (1:6), driving four paddles fitted with brushes arranged 180° apart. Water was introduced at a ratio of 1:2 (ginger to water) to aid peeling and lifting action. Performance evaluation was conducted with batch sizes of 10–30 kg and peeling durations of 10–20 minutes. Parameters measured included peeling efficiency, product damage rate, throughput capacity, and labor savings. Results showed an optimum peeling efficiency of 79.4% at 20 kg batch size and 15 minutes duration, with product damage kept below 10%. Throughput capacity ranged between 60–90 kg/hr, and labor savings were significant, reducing processing time by ~75% and manpower by ~60% compared to manual peeling. The study concludes that the machine effectively bridges the gap between manual and industrial systems, offering a cost-effective, hygienic, and efficient solution for ginger processing. Its reliance on locally available materials ensures affordability and ease of maintenance, while its performance demonstrates potential for adoption in rural and semi-industrial contexts.

**Keywords:** Ginger peeling machine, hydraulic action, brush-based mechanism, peeling efficiency, throughput capacity, postharvest engineering.

### REZIME

Rastuća potražnja za đumbirom u prehrambenoj, farmaceutskoj i kozmetičkoj industriji ukazala je na ograničenja ručnog ljuštenja, koje je radno intenzivno, dugotrajno i sklono gubitku proizvoda. Ova studija predstavlja dizajn, izradu i evaluaciju lokalno konstruisane mašine za ljuštenje đumbira namenjene malim i srednjim prerađivačima. Mašina je izrađena korišćenjem gvođenog profila od 3 mm za ram i galvanizovanog čeličnog bubnja (Ø410 mm × 430 mm, debljina 1,5 mm) kao komore za ljuštenje. Pogonski motor od 6 KS, koji radi na 2400 obrtaja u minuti, obezbeđuje snagu preko konusnog zupčanika (1:1) i sistema remenica (1:6), pokrećući četiri lopatice sa četkama raspoređenim pod uglom od 180°. Voda je dodavana u odnosu 1:2 (đumbir:voda) radi olakšavanja ljuštenja i podizanja rizoma. Evaluacija performansi sprovedena je sa količinama od 10–30 kg i trajanjem ljuštenja od 10–20 minuta. Mereni parametri uključivali su efikasnost ljuštenja, stopu oštećenja proizvoda, kapacitet protoka i uštedu rada. Rezultati su pokazali optimalnu efikasnost ljuštenja od 79,4% pri količini od 20 kg i trajanju od 15 minuta, uz oštećenje proizvoda ispod 10%. Kapacitet protoka se kretao između 60–90 kg/h, a ušteda rada bila je značajna, smanjujući vreme obrade za oko 75% i potrebu za radnom snagom za oko 60% u poređenju sa ručnim ljuštenjem. Studija zaključuje da mašina efikasno povezuje ručne i industrijske sisteme, nudeći ekonomično, higijensko i efikasno rešenje za preradu đumbira. Oslanjanje na lokalno dostupne materijale obezbeđuje pristupačnost i jednostavno održavanje, dok performanse pokazuju potencijal za primenu u ruralnim i poluindustrijskim kontekstima.

**Ključne reči:** Mašina za ljuštenje đumbira, hidraulična akcija, mehanizam sa četkama, efikasnost ljuštenja, kapacitet protoka, postžetvena inženjerija.

### INTRODUCTION

Ginger (*Zingiber officinale*) is a globally significant spice crop valued for its culinary, medicinal, and industrial applications. In food processing, peeling is a critical step because the outer skin of ginger rhizomes harbors soil particles, fibrous tissues, and microbial contaminants that compromise product quality and safety. Proper peeling enhances the appearance, taste, and shelf life of ginger products, thereby improving their marketability for both domestic consumption and international trade (Srikaeo, Khamphu, & Weerakul, 2020; Rahman, 2018).

Traditionally, peeling has been performed manually using knives or abrasive scrubbing. While simple and accessible, these methods are labor-intensive, time-consuming, and inconsistent in quality. Manual peeling often results in excessive removal of edible portions, leading to high material wastage, while the

irregular shape and thin skin of ginger rhizomes make the process ergonomically demanding (Ginger Processing Expert, 2025). In large-scale operations, these limitations translate into reduced productivity, higher processing costs, and increased worker fatigue (Jayashree & Viswanathan, 2012).

Mechanical peeling technologies have been introduced to address these inefficiencies, employing abrasive surfaces, rotating drums, or cutting blades. However, most existing designs achieve efficiencies below 70%, frequently leaving skin unremoved or damaging the rhizomes. Abrasive machines tend to cause excessive flesh removal, while blade-based systems struggle with irregular rhizome shapes (Onwukwe, 2020; Lonkia Machinery, 2025; Adhityan et al., 2025). Hand-operated designs, though affordable, remain unsuitable for commercial applications due to limited capacity and reliance on manual labor. These shortcomings highlight the need for improved mechanical

solutions that balance efficiency, product quality, and affordability (Zackry, 2025).

This study presents the design, fabrication, and evaluation of a modified ginger peeling machine developed using locally available materials. The machine integrates a hydraulic action assisted by a brush-based peeling mechanism, with optimized drum dimensions, transmission ratios, and controlled water incorporation to enhance peeling efficiency while minimizing product damage. The hydraulic action facilitates lifting and softening of rhizomes, while the brushes ensure uniform removal of skin with reduced loss of edible flesh. By bridging the gap between manual and industrial systems, the modified design aims to provide a cost-effective, hygienic, and scalable solution for small-to-medium scale processors. The research contributes to postharvest engineering by demonstrating how mechanical innovation can improve efficiency, reduce waste, and support rural agro-processing industries.

**MATERIALS AND METHODS**

The modified ginger peeling machine was constructed using locally available materials selected for durability, food safety, and mechanical performance. The frame was fabricated from 3 mm × 1.5" angle iron to provide structural rigidity. The peeling chamber was made of galvanized steel (Ø410 mm × 430 mm, thickness 1.5 mm), chosen for its corrosion resistance and hygienic properties.

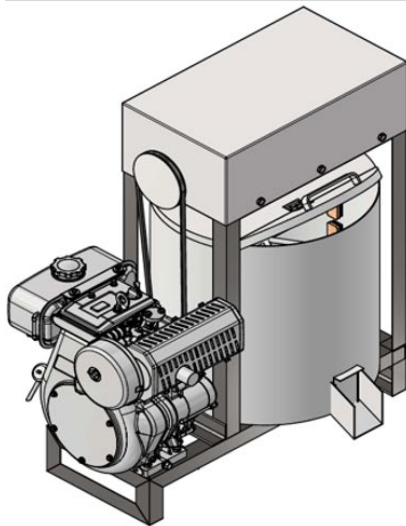


Fig. 1. Isometric view of the ginger peeling machine

The peeling mechanism consisted of four paddles fitted with brushes, arranged in pairs 180° apart to ensure uniform peeling action. A 6 hp prime mover operating at 2400 rpm supplied power, transmitted through a bevel gear (1:1) and pulley system (1:6) to achieve torque multiplication and speed reduction. Shafts of 25 mm diameter were supported by pillow and square bearings to ensure stability and smooth rotation. Safety guards and an emergency stop mechanism were incorporated to protect operators during use.

**Design analysis**

The design analysis of the ginger peeling machine was carried out to ensure that the selected dimensions, materials, and power system would meet the operational requirements of efficiency, durability, and safety. The analysis focused on critical parameters such as shaft diameter, drum volume, motor power, and transmission ratios.

**Shaft diameter**

The shaft diameter was determined based on combined torsional and bending stress using the distortion energy theory (Budynas & Nisbett, 2015):

$$d = \left( \frac{16}{\pi} \times \frac{\sqrt{M_b^2 + M_t^2}}{\sigma_{allow}} \right)^{1/3}$$

Where:

$M_b$  = bending moment (Nm)

$M_t$  = torsional moment (Nm)

$\sigma_{allow}$  = allowable shear stress of shaft material (MPa)

The torsional moment was determined from the transmitted torque:

$$M_t = \mu \times m \times g \times r$$

$$= 0.35 \times 30 \times 9.81 \times 0.205 = 21.1 \text{ Nm}$$

Where  $\mu = 0.35$  (friction coefficient for wet ginger on brush surface),

$m = 30 \text{ kg}$  (maximum batch load),

$g = 9.81 \text{ m/s}^2$ , and

$r = 0.205 \text{ m}$  (drum radius).

The bending moment was estimated from the paddle assembly weight (approximately 5 kg) acting over the shaft span (0.43 m)

$$M_b = \frac{W \times L}{4}$$

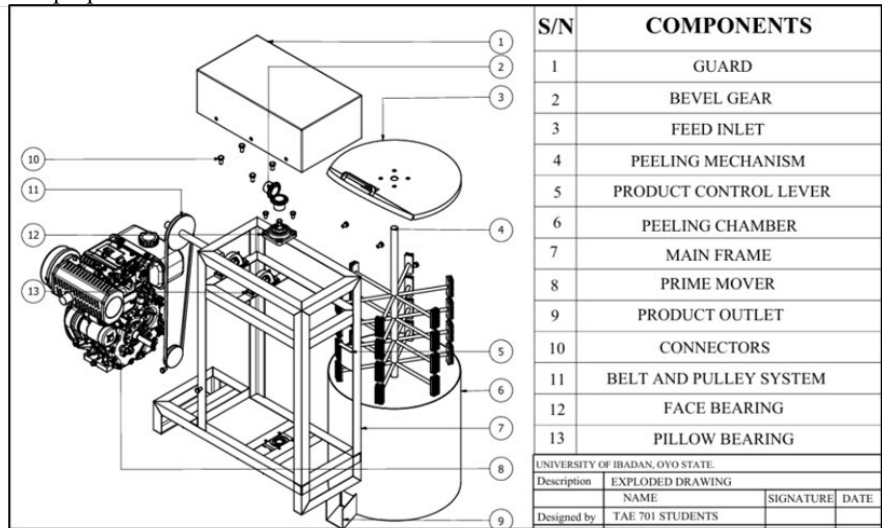


Fig. 2. Exploded drawing of the machine

$$= \frac{(5 \times 9.81) \times 0.43}{4} = 5.3 \text{ Nm}$$

The combined moment:

$$\sqrt{M_b^2 + M_t^2} = \sqrt{5.3^2 + 21.1^2} = \sqrt{28.1 + 445.2}$$

$$= 21.75 \text{ Nm}$$

Using allowable shear stress for mild steel,  $\sigma_{allow} = 55 \text{ MPa}$ :

$$d = \left( \frac{16}{\pi} \times \frac{21.75}{55 \times 10^6} \right)^{1/3} = 0.01938 \text{ m} \approx 19.4 \text{ mm}$$

A standard shaft diameter of **25 mm** was selected as the nearest commercially available size above the calculated minimum, providing a safety factor of approximately 1.3. This dimension was supported by pillow and square bearings to ensure stability and smooth rotation.

**Drum volume and capacity**

The peeling drum was designed with a diameter of 410 mm and height of 430 mm. The drum volume was calculated as:

$$V = \pi r^2 h$$

$$= \pi \times (0.205)^2 \times 0.43 = 3.1416 \times 0.04203 \times 0.43$$

$$= 0.0569 \text{ m}^3$$

With the bulk density of ginger rhizomes estimated at 600–700 kg/m<sup>3</sup>, and accounting for a practical drum fill of approximately 60%, the effective batch capacity is:

$$m_{batch} = \rho \times V \times 0.60$$

$$= 650 \times 0.0569 \times 0.60 \approx 22.2 \text{ kg}$$

This confirms the operational batch range of 20–30 kg reported during performance evaluation, as the drum accommodates up to approximately 34 kg at full fill.

**Motor power requirement**

The required motor power was determined from the rotational speed and operating torque: Engineers Edge. (2024)

$$P = \frac{2\pi NT}{60}$$

Where:

*P*= power (W)

*N*= rotational speed at the drum (rpm)

*T*= operating torque (Nm)

The drum speed was derived from the motor speed (2400 rpm) through the pulley system (ratio 1:6):

Using the operating torque *T*= 21.1 Nm (as derived under shaft design):

$$P = \frac{2\pi \times 400 \times 21.1}{60} = \frac{53,066}{60} = 884 \text{ W} \approx 1.19 \text{ hp}$$

A 6 hp (4,476 W) prime mover was selected, providing a design safety factor of approximately 5.1. This accounts for start-up inertia, resistance from the water-ginger mixture, brush drag, and transmission losses through the bevel gear and pulley system consistent with standard practice in agricultural machinery design (ASME B106.1M, 2017).

**Fabrication process**

Fabrication followed recognized engineering practices and relevant ASME standards. The frame was welded according to ASME BPVC Section IX, ensuring structural strength. The chamber was rolled and welded per ASME B31.3 standards, while brush clearance and paddle alignment adhered to ASME Y14.5 tolerancing guidelines. Assembly included installation of the power transmission system, peeling mechanism, and safety features.

**Operating principle**

The ginger peeling machine operates on the principle of combined mechanical brushing and hydraulic action. Ginger rhizomes are loaded into the peeling chamber through the feed inlet, along with water introduced at a ratio of 1:2 (ginger to water). The presence of water serves multiple functions: it softens the skin, reduces frictional heat, and assists in lifting the rhizomes from the bottom of the drum to the active peeling zone.

As the prime mover (6 hp, 2400 rpm) drives the system, power is transmitted through the bevel gear (1:1 ratio) and pulley system (1:6 ratio) to the vertical shaft inside the drum. This shaft rotates the paddles fitted with brushes, which are arranged in pairs 180° apart. The brushes contact the ginger rhizomes, gently scrubbing away the skin while minimizing damage to the edible flesh.

The smooth internal surface of the drum, combined with the 40 mm clearance between brushes and drum wall, ensures that peeling is achieved primarily through controlled brushing rather

than abrasive scraping. This design reduces fragmentation and preserves product quality. The rotational motion also facilitates continuous tumbling of the rhizomes, ensuring uniform exposure to the brushes.

Peeled ginger is discharged through the product outlet, while waste material (skin and debris) is collected separately via the waste collection system. The inclusion of protective guards and an emergency stop mechanism ensures safe operation, while ergonomic design features such as accessible loading and discharge points enhance usability.

**Testing and evaluation**

The performance evaluation of the ginger peeling machine was conducted to determine its efficiency, throughput, product quality, and labor savings compared to manual peeling. Testing was carried out under controlled conditions, with variations in drum speed, batch size, and peeling duration to identify optimum operating parameters.

*Experimental setup*

The machine was tested using freshly harvested ginger rhizomes. Water was introduced at a ratio of 1:2 (ginger to water) to facilitate peeling. Batches of ginger ranging from 10–30 kg were loaded into the drum, and peeling was performed at different durations (10, 15, and 20 minutes). Drum speed was adjusted through the pulley system to evaluate its effect on peeling efficiency and product damage.

*1. Peeling efficiency*

Peeling efficiency was determined gravimetrically, following the approach of Holker et al. (2018). Prior to each trial, freshly harvested ginger rhizomes were manually inspected to remove damaged or undersized pieces. A reference sample from the same batch was completely peeled by hand, and the total skin weight obtained (*W<sub>skin\_total</sub>*) was recorded as the baseline for 100% peeling. The total weight of the unpeeled ginger loaded into the machine (*W<sub>t</sub>*) was recorded using a digital weighing scale (accuracy ±0.1 g), and water was introduced at a ratio of 1:2 (ginger to water).

At the end of each peeling duration (10, 15, or 20 minutes), the drum contents were discharged through the product outlet. Skin debris was collected separately from the waste collection system, dried briefly, and weighed (*W<sub>skin\_removed</sub>*). Peeling efficiency (*η*) was then calculated as:

$$\eta = \frac{W_{skin\_removed}}{W_{skin\_total}} \times 100$$

Where:

*W<sub>skin\_removed</sub>*= weight of skin collected from the machine after peeling (g)

*W<sub>skin\_total</sub>*= total skin weight obtained from complete manual peeling of an equivalent sample (g)

Each batch condition was replicated three times and the mean value reported.

*2. Product Damage*

Product damage was assessed by comparing the weight of intact peeled ginger recovered after machine processing to the initial unpeeled batch weight. After discharge, peeled ginger was separated from skin debris and water, rinsed briefly under clean water, drained for 60 seconds, and weighed (*W<sub>p</sub>*). The product damage rate (*D*) was calculated as:

$$D = \left(1 - \frac{W_p}{W_t}\right) \times 100$$

Where:

$W_p$  = weight of peeled ginger recovered after processing (g)  
 $W_t$  = total weight of ginger loaded into the machine before processing (g)  
 $D$  = product damage rate, representing percentage of edible flesh lost during peeling (%)

A damage rate below 10% was set as the acceptable threshold, consistent with values reported in comparable mechanical peeling studies (Holker et al., 2018). Each batch condition was replicated three times and the mean damage rate reported.

### 3. Throughput capacity

Throughput was determined as the mass of ginger processed per unit time (kg/hr).



Fig. 3. Fully fabricated ginger peeling machine



Fig. 4. Peeled ginger

## RESULTS AND DISCUSSION

The performance of the fabricated ginger peeling machine was evaluated in terms of peeling efficiency, product damage rate, throughput capacity, and labor savings. The results are presented in tables and discussed in comparison with findings from other researchers.

### Peeling efficiency

The machine achieved an overall peeling efficiency of 79.4% under optimum operating conditions (20 kg batch size, 15 minutes duration, 400rpm drum speed). This surpasses the efficiency reported by Holker et al. (2018), who achieved 70.2% efficiency using ginger pre-treated with NaOH solution. Unlike chemical pre-treatment methods, the present design achieved higher

efficiency without chemical additives, thereby avoiding contamination risks.

Table 1. Peeling efficiency results

Batch Size (kg)	Peeling Duration (min)	Efficiency (%)
10	10	72.5
20	15	79.4 (optimum)
30	20	76.2

The efficiency increased with batch size up to 20 kg, after which it declined slightly due to overloading and reduced brush contact. Compared to Jayashree & Viswanathan (2012), who reported optimum efficiency at 8 kg batch size and 40 rpm drum speed, the present machine demonstrates higher capacity and efficiency, making it more suitable for medium-scale processing.

### Product damage

Product damage was consistently low, with flesh loss below 10% under optimum conditions. This is attributed to the smooth drum surface and 40 mm clearance between brushes and drum wall, which minimized excessive scraping.

Table 2. Product damage rate

Batch Size (kg)	Peeling Duration (min)	Damage Rate (% flesh loss)
10	10	8.5
20	15	9.2
30	20	11.0

The damage rate compares favourably with Holker et al. (2018), who reported mass loss of 4.13% under hot water soaking conditions. While their method achieved slightly lower mass loss, it required pre-treatment, whereas the present machine achieved acceptable damage rates without chemical or thermal treatment.

### Throughput capacity

Throughput capacity ranged between 60–90 kg/hr depending on batch size and peeling duration. Optimum throughput was achieved at 30 kg batch size and 20 minutes duration, yielding ~90 kg/hr.

Table 3. Throughput capacity

Batch Size (kg)	Peeling Duration (min)	Throughput (kg/hr)
10	10	60
20	15	80
30	20	90

The throughput capacity of the present machine is significantly higher than that of the hand-operated peeler developed by Jayashree & Viswanathan (2012), which processed only 6–10 kg per batch. Although industrial peelers may achieve higher capacities, the present design bridges the gap between manual and industrial systems, making it suitable for small-to-medium scale processors.

### Labor savings

The machine reduced peeling time and labor requirements substantially compared to manual peeling.

Table 4. Labor savings

Method	Processing Time/20 kg	Labor Requirement
Manual peeling	~60 minutes	2–3 operators
Machine peeling	~15 minutes	1 operator

Compared to manual peeling, which is labor-intensive and time-consuming, the machine reduced processing time by ~75% and labor requirement by ~60%. This finding is consistent with other mechanical designs that emphasize labor reduction as a key advantage.

## CONCLUSION

The design, fabrication, and evaluation of the ginger peeling machine have demonstrated the feasibility of developing a locally sourced, cost-effective, and efficient solution for small-to-medium scale ginger processors. The machine, constructed from angle iron and galvanized steel, and powered by a 6 hp prime mover, achieved an overall peeling efficiency of 79.4%, surpassing the performance of many existing mechanical designs. The brush-based peeling mechanism, combined with water integration (hydraulic action) at a 1:2 ratio, proved effective in removing ginger skin while minimizing edible flesh loss (<10%). Throughput capacity ranged between 60–90 kg/hr, with optimum performance at 20 kg batch size and 15 minutes peeling duration. Compared to manual peeling, the machine reduced processing time by approximately 75% and labor requirements by 60%, thereby enhancing productivity and reducing operator fatigue.

The results confirm that the machine bridges the gap between manual and industrial systems, offering a practical solution for rural and semi-industrial contexts. Its reliance on locally available materials and simple design ensures affordability, ease of maintenance, and sustainability.

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