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Design and Fabrication of Garlic Peeling Machine

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Abstract

This paper provides a review of garlic peeling machines along with relevant research. The study outlines the key factors affecting the garlic peeling process and suggests design alternatives for garlic peeling machines. These recommendations are based on a thorough analysis of the garlic peeling process. Garlic is a highly valuable and economical plant with extensive applications in medicinal, culinary, and Ayurvedic practices. However, the process of garlic peeling is labour-intensive, time-consuming, and often inefficient. Traditional peeling methods, which are still widely used, are not only unhygienic but also result in significant damage to garlic cloves. While mechanical peelers exist, they are often expensive and inaccessible to small-scale industries. This creates a pressing need for the development of an affordable, low-cost mechanical peeler that can alleviate the manual effort and improve efficiency.

In this study, a cost-effective garlic peeler was designed using angular iron and flat iron for the main frame and structural support. A food-grade rubber layer was applied to a mild steel pipe to create a rubber roller, while an iron bar served as the shaft. A wire mesh was incorporated as a screening component. The physical properties of garlic cloves, including moisture content, dimensions, weight, geometric mean diameter, sphericity, equivalent mean diameter, shape factor, terminal velocity, and drag coefficient, were meticulously analysed. The moisture content of the garlic cloves was measured at 59.36 ± 0.87% (w.b.). At this moisture level, the average length, width, and thickness of the cloves were found to be 25.818 ± 3.743 mm, 10.116 ± 2.209 mm, and 7.34 ± 1.638 mm, respectively. The average weight of a single garlic clove was 1.159 g. Additionally, the geometric mean diameter, sphericity, equivalent mean diameter, and shape factor were calculated to be 12.422 mm, 0.481, 13.03 mm, and 0.218, respectively. The terminal velocity and drag coefficient were determined to be 18.941 m/s and 0.416 at a moisture content of 59.08 ± 0.82% (w.b.).

The estimated cost of the developed peeler was approximately ₹10,000, making it a viable and economical solution for small-scale industries. This innovation aims to reduce the drudgery associated

	with traditional peeling methods while providing a hygienic and efficient alternative to costly mechanical peelers.

Introduction

Garlic (Allium sativum L.), an underground perennial bulb, is a significant vegetable spice belonging to the Liliaceae family. The bulb consists of a cluster of 12 or more segments, known as cloves, which are essentially swollen leaf bases. Both the cloves and the entire bulb are encased in a thin, papery white skin. The cloves, being the edible and economically valuable part of the garlic plant, are widely utilized for culinary and medicinal purposes. Garlic is a rich source of phenolic compounds, phosphorus, sulfur, zinc, selenium, and vitamins A and C, along with trace amounts of calcium, sodium, iron, manganese, and B vitamins. Cultivated for centuries across the globe, particularly in Asia, garlic holds a prominent place in global agriculture. India, one of the leading producers of garlic, cultivated 238.760 thousand hectares, yielding 3221.380 thousand tons during the year 2013-14 (Spice Board of India, 2014). Gujarat emerged as the top producer, contributing 277.455 thousand tons in 2011-12, followed by states like Madhya Pradesh, Uttar Pradesh, Rajasthan, Assam, Punjab, and Maharashtra.

Garlic is consumed both in its fresh green form and as a dried spice, adding flavor to a variety of vegetarian, non-vegetarian dishes, and pickles. It is also used to mask the odor of salted meat and fish. In many countries, dehydrated garlic in powdered or granulated form has replaced fresh bulbs in various applications. The processing of garlic involves several steps, including bulb breaking, peeling, dehydration, and grinding. Among these, peeling is a critical and essential operation that must be performed before any further processing. The process involves removing the thin, inedible membranous skin from the cloves. However, the small size of the cloves makes peeling a labor-intensive and time-consuming task. Traditional peeling methods, such as hand peeling, flame peeling, oven peeling, and chemical peeling, are either inefficient, unhygienic, or damaging to the cloves. Therefore, there is a need for an efficient peeling device that can gently remove the skin without compromising the clove's shape, structure, or aroma.

Several researchers have attempted to develop machine-operated garlic peelers, often based on the cylinder and concave concepts. However, these machines are typically power-intensive, bulky, and expensive, limiting their accessibility to small-scale producers and consumers. To address these challenges, this study was undertaken with the primary objective of designing and fabricating a hand-operated, user-friendly garlic peeler. The specific objectives include:

a) studying the physical characteristics of garlic cloves,

b) selecting appropriate engineering materials for the peeler's fabrication, and

c) designing a cost-effective, hand-operated garlic peeler.

The proposed peeler aims to overcome the limitations of traditional methods, reduce peeling time, and enhance the overall efficiency of garlic processing. By providing a practical and affordable solution, this innovation has the potential to boost garlic processing and export, benefiting both producers and consumers alike. Additionally, the development of such a device could significantly reduce the drudgery associated with manual peeling, making it a valuable tool for small-scale industries and households.

Materials And Method

The paraphernalia used in this study included fresh garlic corridor, a DC geared motor, a speed controller, a cracker motor, a 12V power force, and an acrylic structure. The DC geared motor, which converts electrical energy into mechanical energy, was employed to drive the shelling medium. A speed controller was integrated to regulate the motor's speed as per functional conditions. A DC cracker motor was employed to separate and remove the cocoon from the garlic cloves during the shelling process. The entire system was powered by a 12V power force, which is generally used for its effectiveness and vacuity. The acrylic structure, known for its optical chastity and durability, was chosen for its felicity in technical operations, icing the machine's stability and functionality.

Fresh, well- progressed, and cured garlic bulbs were carried from the original request of Bapatla, Guntur District, Andhra Pradesh. The bulbs were manually broken into individual cloves, and steady- sized corridor were graded after removing the thin, papery skin. paraphernalia demanded for the fabrication of the bull were sourced from original attack stores in Bapatla. The moisture content of the garlic corridor was determined using the hot air rotisserie system. Samples importing 15 g each were placed in moisture boxes and dried in a hot air rotisserie(Yorco, Model YSI- 431) at 100- 105 °C for 2 hours. After cooling in a desiccator, the samples were counted until a constant weight was achieved, and the moisture content was calculated using the standard formula.

$$Mc = \frac{\text{Initial Weight of Sample} - \text{Final Weight of Sample}}{\text{Original Weight}} X100$$

Geometric mean fringe (Dg) = $(LWT)^{1/3}$

Sphericity (Φ)= $\frac{(LWT)^{1/3}}{L}$

Original mean fringe (De) = $\frac{(6Vsingle)^{1/3}}{\pi^{1/3}}$

Vsingle = $\frac{100 \text{ grain weight } 10^6}{PD \text{ X } 100}$

Shape factor (Z)= $\pi/6 \; Dg^3/De^3 \; \Phi$

Where,
Dg =Geometric mean Fringe (mm)
L= Longest intercept (mm)
W = Longest block normal to L (mm)
T= Longest block normal and W (mm)
De = Equivalent mean fringe (mm)
Vsingle = Volume of single speck (mm^2)
PD = flyspeck density (kg/ m3)
Φ= Sphericity
Z= Shape factor

The terminal haste of the garlic corridor was measured using a wind lair with a vertical conduit. A centrifugal pump generated an air current in the conduit, allowing the cloves to float. The air haste was gradually increased until the corridor was suspended, and the haste was measured using a digital anemometer. The drag measure was also calculated using the terminal haste and other applicable parameters. These measures were vital for understanding the aerodynamic parcels of the garlic corridor, which told the design and effectiveness of the shelling medium.

A1 V1 = A2 Vt
where,
A1 = the area of the tube's cross-section (in square meters, m^2).
V1 = haste of air in the tube(m/ s)
A2 = cross sectional area of vertical conduit(m2)
Vt = terminal haste of air in the vertical conduit(m/ s)

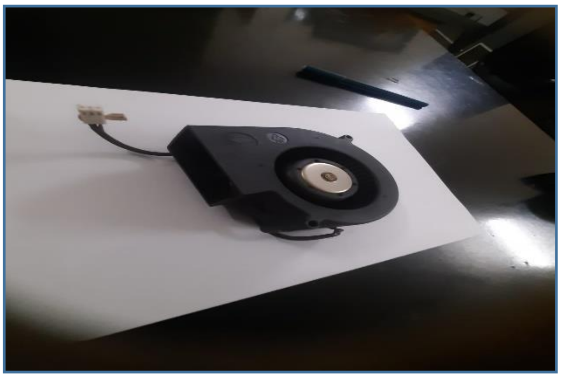
Drag measure was calculated using the following formula

$$C_d = \frac{2\, mg\, (\rho_p - \rho_a)}{V_t^{\,2}\, \rho_a\, \rho_p\, A_p}$$

where,
m = Mass of single speck (kg)
g = Acceleration due to staidness (m/s 2)
Vt = Terminal hastel (m/s)
p = flyspeck density (kg/m3)
a = Density of air (kg/ m3)
Ap = Projected area of flyspeck (m2) = $\pi/4$ De^2
De = Equivalent mean fringe (m)

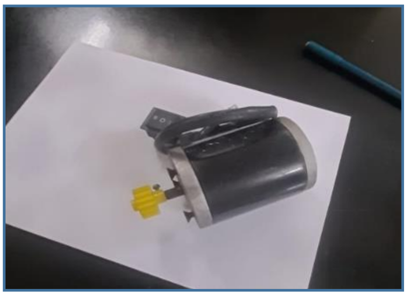
Materials Used In Fabrication Of Garlic Peeler

By incorporating these materials and methodologies, the study aimed to develop a hand-operated, user-friendly garlic peeler that addresses the limitations of traditional peeling methods. The proposed design not only reduces peeling time but also minimizes damage to the cloves, ensuring better quality and hygiene. This innovation has the potential to significantly enhance garlic processing, particularly for small-scale producers, by providing an affordable and efficient solution. Additionally, the use of locally available materials and simple fabrication techniques makes the peeler accessible to a wider range of users, further boosting its practical applicability.



A wire mesh with a thickness of 1 mm and an opening size of 1 mm^2 was employed as the abrasive screen. It was cut to dimensions of 230 × 200 mm and securely attached to a concave structure. The main frame of the garlic peeler was constructed as a trapezoidal shape using angular iron. The height of the main frame measured 580 mm. The bottom frame had rectangular dimensions of 400 × 470 mm, while the upper frame was slightly smaller, measuring 300 × 370 mm.

The frame was fixed to the concave surface, allowing the garlic segments to be peeled primarily through a shearing action, with slight compression involved.



The feed hopper, designed as a rectangular box, had one vertical side and the other tapered towards the bottom to encourage a smooth flow. It was made from 1mm galvanized iron sheet, with dimensions of 180 mm in length, 100 mm in breadth, and 170 mm height (tapering to 100 mm on both sides). The bottom opening of the hopper was 50 mm wide, with a length of 180 mm. This design ensures that the garlic segments are uniformly distributed across the cylinder, which then rubs them against the concave for peeling. The hopper was also equipped with a galvanized iron sheet to regulate the flow of the segments into the cylinder.

The rubber roller, made from a hollow mild steel tube, was closed on both ends with caps. The tube had a total length of 220 mm and a diameter of 62.5 mm. The roller was coated with a 180 mm long, 6 mm thick layer of food-grade silicone rubber. Thin 1 mm wires were attached along the length of the rubber at 10 mm intervals, as shown in the diagram.

An iron shaft was welded to the caps of the cylinder, allowing it to be mounted on the frame using bearings. The shaft was designed to accommodate different drive systems. One end of the shaft featured a provision for attaching a handle to manually operate the device, while the other end had a 20 mm diameter to attach a pulley, which transferred motion to the blower.

The frame was thoughtfully designed for user convenience, incorporating space for the exit chutes and blower. The blower, a smithy blower made of cast iron, had a circular outlet for airflow. The drive for the blower was taken from the shaft of the cylinder, and it was equipped with a 25 mm diameter pulley, while the blower's shaft had a diameter of 50 mm.

Fabrication Of Machine

The main frame of the garlic peeler was designed to support three key units: the feeding unit, the cylinder-concave unit, and the blower. Angular iron was arc-welded to construct the main frame according to specified dimensions. An angle frame, bent into a C-shape with dimensions of 80 mm in height and 200 mm in length, was welded to two opposite sides of the top face of the frame. This design allowed for the horizontal face to accommodate bearings, which were secured using fasteners. The feeding unit consisted of a hopper, which was spot-welded to one side of the cylinder-concave unit. A feed regulator, made from a 1 mm thick galvanized iron sheet, was incorporated to control the flow of garlic segments and prevent spillage. This regulator could be adjusted up or down to open or close the hopper opening based on the feed requirement. A slanted galvanized iron plate was positioned between the hopper opening and the concave to guide the segments into the clearance between the concave and the rubber roller, preventing them from jumping off the roller. The hopper was placed slightly to one side in a slanted position for optimal feeding.

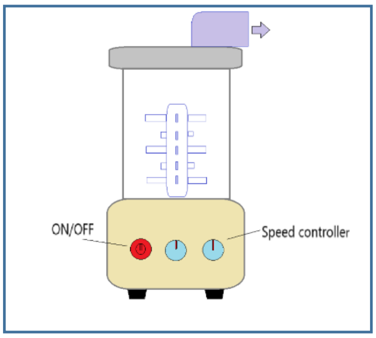
The cylinder-concave unit comprised a rubber roller, a concave, a wire mesh, and a cylinder. A shaft passed through the rubber roller, extending from the roller caps to facilitate additional functions. This shaft was supported by 32 mm diameter bearings mounted on either side of the angle frames. The wire mesh was securely fastened onto the concave, which was positioned beneath the rubber roller. The clearance between the roller and the concave was fixed at 20 mm on the feeding side and adjustable from 8 to 12 mm on the outlet side using a nut-and-screw mechanism. To set the clearance, two wooden pieces of 8 mm and 20 mm thickness were placed on the roller near the inlet and outlet, respectively, and tied in place with a rope. The concave was then adjusted and arc-welded into position. A screw-and-nut arrangement at the bottom allowed for fine-tuning the clearance by rotating the screw clockwise to decrease or counterclockwise to increase the gap. The concave and the nut-screw mechanism were supported by two flat iron rings placed on either side of the rubber roller.

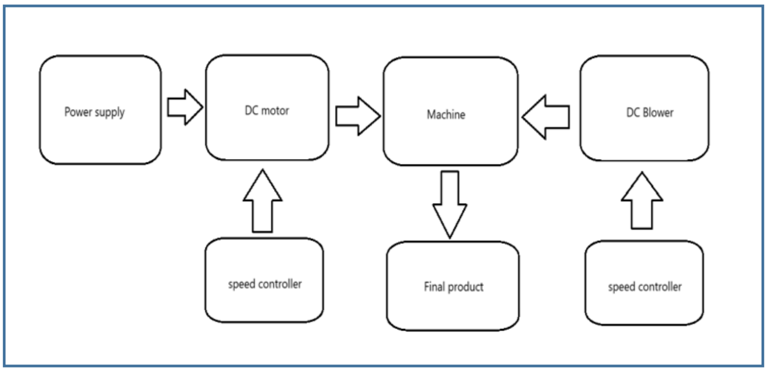
One end of the shaft was fitted with a handle for manual operation, while the other end was equipped with a pulley to drive the blower. The entire cylinder-concave unit was enclosed within a cylinder measuring 210 mm in diameter and 270 mm in length. Flat iron was bent to match the cylinder's shape and arc-welded to the main frame to provide additional support. The blower was positioned 120 mm above the bottom frame.

Chutes, made from 1 mm thick galvanized iron sheets, were spot-welded to the cylinder at the outlet. The top chute measured 170 × 50 mm and tapered to 80 × 50 mm at the bottom. This chute was connected to another chute from the blower, measuring 420 × 50 × 50 mm. An additional chute, 130 × 80 × 50 mm in size, was welded 80 mm from the blower.

During operation, garlic segments were fed into the hopper and flowed through the clearance between the concave and the rubber roller. As the segments underwent abrasion, the peeled and unpeeled cloves, along with the husk, moved through the chute into the blower's chute. The blower's air stream separated the husk from the cloves, while the peeled and unpeeled segments rolled down into the outlet chute. Unpeeled segments were manually separated and reintroduced into the hopper for reprocessing. This design ensures efficient peeling while minimizing damage to the cloves, making it a practical solution for small-scale garlic processing. Additionally, the adjustable clearance and manual feed regulation allow for flexibility in handling garlic cloves of varying sizes, enhancing the machine's versatility and usability.

Preliminary Design





Block Diagram

Results And Discussion

The moisture content of the garlic segments was determined to be 59.36 ± 0.87% (w.b.). At this moisture level, the average length, width, and thickness of the garlic segments were measured as 25.818 ± 3.743 mm, 10.116 ± 2.209 mm, and 7.34 ± 1.638 mm, respectively. These dimensions played a crucial role in determining the optimal clearance between the concave and the rubber roller to ensure efficient peeling. The average weight of individual garlic segments was found to be 1.159 g at the same moisture content. Additionally, the geometric mean diameter, sphericity, equivalent mean diameter, and shape factor of the garlic segments were calculated to be 12.422 mm, 0.481, 13.03 mm, and 0.218, respectively, at a moisture content of 59.36 ± 0.87% (w.b.).

At a slightly lower moisture content of 59.08 ± 0.82% (w.b.), the terminal velocity and drag coefficient of the garlic segments were determined to be 18.941 m/s and 0.416, respectively. The terminal velocity is a critical parameter for designing blowers used in the aeration and separation of lighter materials, such as peel and husk, during the peeling process. These physical and aerodynamic properties of garlic segments provided essential insights for optimizing the design and operation of the garlic peeler. By incorporating these findings, the developed peeler ensures efficient peeling with minimal damage to the cloves, making it a practical and cost-effective solution for small-scale garlic processing. Furthermore, the adaptability of the machine to handle garlic cloves of varying sizes and moisture levels enhances its versatility, making it suitable for a wide range of users. This innovation not only reduces manual labor but also improves the overall quality and hygiene of the peeled garlic, contributing to the advancement of garlic processing technologies.

Cost Estimation

Cost of Peeler Cost of peeler was ₹ 7,580/- The cost of each material used is given in

SR NO.	ESTIMATION	COST (₹)
1	High Speed Motor	1000
2	Speed Regulator Circuit	350
3	Blower Motor	700
4	Rubber Blades For Pilling	600
5	100 Mm Dia. Acrylic Tube	800
6	5mm Acrylic Sheet 2x2 Feet	700
7	Speed Controller	680
8	POWER SUPPLY 12v / BATTERY	850
9	Design And Fabrication	1900
TOTAL		**7,580/-**

Summary And Conclusions

The moisture content of the garlic segments was measured at 59.36 ± 0.87% (w.b.). At this moisture level, the dimensions of the garlic segments, including length, width, and thickness, were determined using digital Vernier calipers, while the weight of each segment was measured using an electronic balance. The average length, width, and thickness of the garlic segments were found to be 25.818 ± 3.743 mm, 10.116 ± 2.209

mm, and 7.34 ± 1.638 mm, respectively. The average weight of individual garlic segments was calculated to be 1.159 g. Additionally, the geometric mean diameter, sphericity, equivalent mean diameter, and shape factor of the garlic segments were determined to be 12.422 mm, 0.481, 13.03 mm, and 0.218, respectively. At a slightly lower moisture content of 59.08 ± 0.82% (w.b.), the terminal velocity and drag coefficient were found to be 18.941 m/s and 0.416, respectively. These parameters are essential for designing efficient blowers to separate lighter materials like husk and peel during the peeling process.

The estimated cost of the garlic peeler was approximately ₹10,000, making it an affordable solution for small-scale industries and individual users. The design of the peeler, based on the physical and aerodynamic properties of garlic segments, ensures efficient peeling with minimal damage to the cloves. By incorporating adjustable clearances and user-friendly features, the peeler addresses the limitations of traditional peeling methods, reducing labor and improving hygiene. This innovation has the potential to significantly enhance garlic processing, particularly for small-scale producers, by providing a cost-effective and efficient alternative to manual peeling. Furthermore, the use of locally available materials and simple fabrication techniques makes the peeler accessible to a wider audience, promoting its adoption in rural and semi-urban areas. Overall, the development of this peeler represents a significant step forward in garlic processing technology, offering both economic and operational benefits.

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