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Economic feasibility of small scale garlic peeler

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Abstract
Garlic is widely used as a condiment, for medicinal and pharmaceutical preparations. Traditional methods of garlic peeling are laborious, time and cost intensive. In this paper, major focus has been laid on testing economic feasibility of small scale developed garlic peeler as our markets are mainly dominated by small scale manufacturing and processing units. Taking into account the manual peeling, the process is highly laborious and time consuming and also there occurs shortage of labor during peak seasons, ultimately adding more cost to peeling operation. Moreover, already available units for garlic peeling are costly and not affordable by small scale entrepreneurs. So, the developed garlic peeling machine will be substantial in serving the small scale entrepreneurs and processing units.

Keywords: Garlic, garlic peeler and techno- economic evaluation

Introduction
Garlic (*Allium sativum L.*), the spice of human life is one of the most important perennial bulb crop of lily family (Lilaceae). It is used as the spice or condiment throughout the world. Garlic is rich source of carbohydrates, proteins and phosphorous. The fresh peeled garlic cloves contain 60-65% (wb) moisture, 6.30% protein, 0.10% fat, 1.0% mineral matter, 0.80% fiber, 29.0% carbohydrates, 0.03% calcium, 0.31% phosphorous, 0.001 iron, 0.40 mg/100g nictonic acid and 13mg/100g vitamin C (Brondnitz *et al* 1971) [2]. Garlic contains allicin which has antioxidant, antibacterial and antibiotic properties (Augusti 1996) [1]. The demand for garlic peeling has grown at increasing rate over many decades owing to its classification as "functional food" that enhances the nutrition and health along with imparting taste. To utilize this functional food, garlic peeling is one of the most important and essential key unit operations prior to any subsequent processing activity. During garlic peeling, thin membrane skin is to be removed off from the whole segment. Various methods of garlic peeling known are lye peeling, submergence in warm water, oven peeling and flame peeling. All these traditional methods are laborious, time and cost intensive with low processing speed and peeling efficiency. The abrasion gadgets already developed are for large scale purposes with high investment cost. So, keeping in view the aspects of time, cost and economics, this small scale garlic peeling machine has been developed which will be instrumental in making peeling process easy at very low expense.

Material and Methods
Small scale garlic peeler with capacity of approximately 15kg/hr was designed (in AutoCAD) and was fabricated at Department of Processing and Food engineering, Punjab Agricultural University, Ludhiana. Various engineering properties like average length, average width, average thickness, geometric mean diameter, sphericity, true density, bulk density, porosity, angle of repose, coefficient of external and internal friction were evaluated initially to design and develop the machine. The developed machine was purposed at low cost and easy to fabricate at small scale to achieve effective peeling of garlic cloves. Small scale power operated garlic peeler was fabricated consisting of hopper, wooden roller, cylindrical cover, blower and power transmission unit. Each and every part was fabricated taking into the size, capacity and its cost effectiveness. Later on techno-economic performance evaluation was carried out on the basis of yield of peeled and unpeeled garlic, peel separation, effect of rotational speed and peeling pretreatments on peeling efficiency and peeled clove recovery, quality traits of peeled cloves obtained and power consumption. The percentages of various fractions were obtained using the following formulae:

$$\text{Percentage of peeled cloves} = \frac{W_p}{W_p + W_u} \times 100$$

Where, W_p – weigth of peeled cloves
W_u – weigth of unpeeled cloves

$$\text{Percentage of unpeeled cloves} = \frac{W_u}{W_p + W_u} \times 100$$

Where W_p – weigth of peeled cloves
W_u – weigth of unpeeled cloves

$$\text{Percentage peeled clove recovery} = \frac{W_p}{W} \times 100$$

Where W_p – weigth of peeled cloves
W – weight of garlic cloves

Machine peeling capacity

$$C_p = \frac{L_b}{(T_1 + T_2 + T_3) \times 1000} \text{ ton/h}$$

The developed garlic peeler eas evaluated using the control (no treatment), hot water pretreatment (80-90 °C for 2 minutes) and hot air pretreatment (60 °C for 1 hour @ 2 m/s, convective tray drying) samples with combination of roller speed of 300, 400 and 500 rpm for all the pretreatments. Further, economic analysis was done to test the feasibility of machine taking into account the total cost which included fixed cost, variable cost and cost of operation as compared to mannual peeling process.

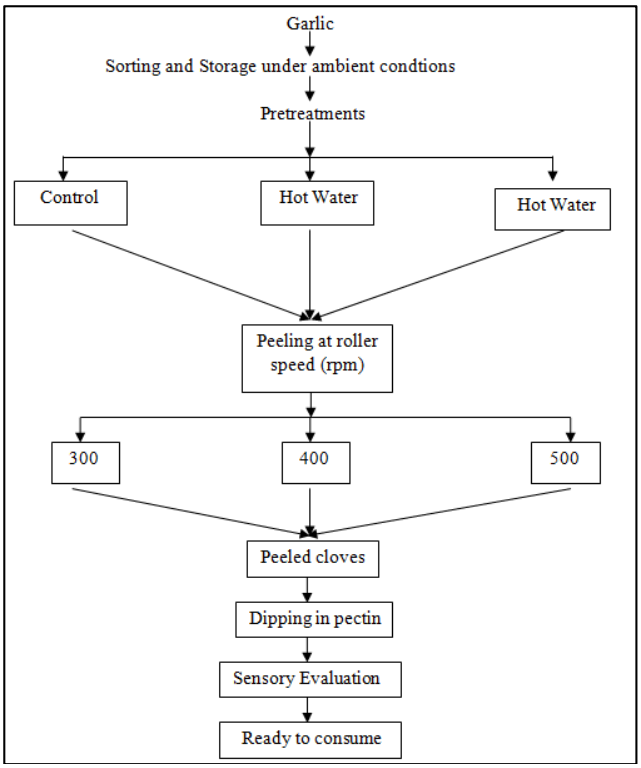

Fig 1: Protocol for clove peeling process

The peeled samples were examined at regular intervals for the purpose of sensory evaluation as per the rating given and calculated of 9 point hedonic scale. The analysis of performance evaluation was done using ANOVA technique (SAS technique) and significant difference was evaluated among the various parameters at $p<0.05$. (Table 1).

Table 1: Sensory evaluation scale

Scale	Condition	Rating
Visual appearance	Very good	5
	Good	4
	Normal	3
	Limited quality	2
	Not acceptable	1

Results and discussion

Different engineering properties of peeled cloves were calculated as average length, a (21.002 ± 3.087 mm), average width, b (9.053 ± 1.622 mm), average thickness, c (7.168± 1.285 mm), geometric mean diameter, D_p (11.048± 1.552 mm) and sphericity, ϕ (0.526±0.189). The average values of bulk density, true density and porosity were reported as 0.556± 0.019 g/cc, 1.169± 0.038 g/cc and 52.413±1.899% respectively. The coefficient of external friction was found to be 0.366 and 0.772 on wooden and GI sheet and coefficient of internal friction was 0.826 respectively. Angle of repose was 25.529º. Similar results were presented by Haciseferogullari *et al* 2005 and Masoumi *et al* 2006 [4, 7] for the whole garlic segments.

Table 2: Engineering properties of peeled garlic cloves

Characteristics	Mean (SD)
Length (mm)	21.002 (3.087)
Width (mm)	9.053 (1.622)
Thickness (mm)	7.168 (1.285)
Geometric mean diameter (mm)	11.048 (1.552)
Sphericity	0.526 (0.189)
Bulk density (g/cc)	0.556 (0.019)
True density (g/cc)	1.169 (0.038)
Porosity (%)	52.413 (1.899)
Coefficient of external friction	On wood - 0.366
	On GI Sheet - 0.772
Coefficient of internal friction	0.826
Angle of repose	25.529º

Design and Development of small scale garlic peeler

Based on the above calculated engineering properties, a small scale garlic peeler was designed using AutoCAD software and later on fabricated in the departmental laboratory using low cost and easily available material in the market. The details of fabricated components are presented in Table 3.

Table 3: Components of machine

Components	Specifications
Hopper	
Material	MS Sheet (22 gauge)
Dimensiosns of upper part (L×W)	30 × 23 (cm)
Dimensions of lower part (L×W)	17× 9 (cm)
Height from the base of hopper	16 cm
Roller	
Material	Wood
Diameter	130 mm
Length	210 mm
Shaft	
Material	Mild steel
Length	460 mm
Diamter	254 mm
Nylon brushes	
Number of brushes	4
Length of each brush	40 mm
Cylinderical Cover with two hemispherical halves	
Material	MS flat sheet (22 guage)
Length	280mm
Width	235mm
Height	175mm
Belt	B- 30 V belt
Pulleys for power transmission	
Motor and roller pulley	
Type	A type, 2 in number
Diameter	650 mm
Bearings	
Material	Gun metal
Type	P-204
Number	2
Power Mechanism	
Motor	Single phase, DC
hp	1
Volts	220
AMP's	4
Maximum RPM	1500
Duty	Cont
Winding	Shunt
Cleaning unit	
Blower Power	¼ hp single phase driven by 1 hp motor
Main frame	
Material	Angle iron (1/4inches × 6 mm)
Length	630 mm
Width	470 mm
Height	960 mm

Performance testing of small scale garlic peeler

Taking into account the peeling efficiency and peeled clove recovery, the maximum peeling efficiency was observed to be 48.14% for hot air pretreated samples at 400 rpm of roller speed and minimum to be 33.89% at 300 rpm of roller speed for control samples. Comparing the two samples- control and hot air, peeled clove recovery of hot air was higher at one particular roller speed. The effect of roller speed was found to be highly significant. The maximum peeled clove recovery calculated was 39.40% for hot air pretreated samples at 400 rpm and minimum of 27.50% at 300 rpm for control samples (Table 4 and 5). Similar results were reported by Manjunatha *et al* (2012) [6] for the average peeling efficiencies at the corresponding moisture contents of 23.1, 27.7, 33.4 and 40.5%. The efficiencies reported were 79.71, 81.16, 78.27 and 68.73%. It was found that the samples which were hot water pretreated were in good condition but peeling in machine was not successful as the outer skin got adhered to the clove surface and abrasion principle did not work.

Table 4: Average values of peeling efficiencies

Pretreatment	Control		Hot air	
Roller speed(rpm)	**Mean**	**SD**	**Mean**	**SD**
300	33.89	4.80	41.04	1.75
400	36.03	5.94	48.13	3.32
500	43.06	1.75	46.30	2.78

Table 5: Average values of peeled clove recovery

Pretreatment	Control		Hot air	
Roller speed (rpm)	**Mean**	**SD**	**Mean**	**SD**
300	27.50	3.14	33.40	0.43
400	30.45	4.60	39.40	2.44
500	33.45	1.94	34.85	4.93

The results revealed that pretreatment with hot air and peeling at intermediate roller speeds helped in better peeling of cloves and were found to be statistically significant (Table 6 and 7).

Table 6: Analysis of variance (ANOVA) for peeling efficiency

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pretrtmnt	1	2108.777216	2108.777216	121.80	<.0001
Rolr_Speed	2	102.740622	51.370311	2.97	0.0706
Pretrtmnt*Rolr_Speed	2	259.516368	129.758184	7.49	0.0030

Table 7: Analysis of variance for peeled clove recovery

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pretrtmnt	1	608.2202133	608.2202133	38.82	<.0001
Rolr_Speed	2	429.7433600	214.8716800	13.71	0.0001
Pretrtmnt*Rolr_Speed	2	354.9316267	177.4658133	11.33	0.0003

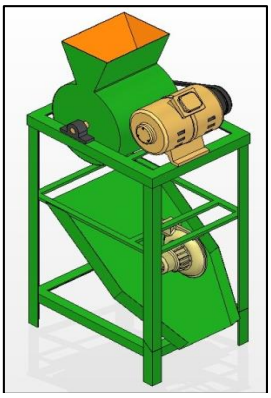

Fig 2: Small Scale Garlic Peeler

Testing of Economic Feasibility of Garlic Peeler

The main aim was to develop a cost effective garlic peeler for small scale purpose so as to satisfy the needs of consumers at small level. Maximum thrust was given on using simple, cheap and easily available components for fabrication purpose. The total manufacturing cost was calculated along with variable cost. Later on the feasibility was also tested with manual peeling process. The details are presented in Table 8 and 9.

Table 8: Economic analysis

No of working hours	10 hrs/day
Fixed Cost	
Cost of machine + Manufacturing	Rs. 19,000
Variable Cost	
Cost of raw material	Rs. 90/Kg
Total material processed in 10 hrs	15 ×10 = 150 kg
Total cost of material processed	Rs 90 × 150 = 13,500
Power consumption	1.2 units/ hr
No. of units consumed in 10 hours	1.2 × 10 = 12
Total electricity charges @ Rs. 8/ unit	Rs. 12×8 = Rs. 96
Labour charges	Rs. 400/day
Maintenance charges	Rs. 500
Total cost of protocol	Rs. 33,496

According to feasibility testing, the total cost of protocol was estimated to be Rs 33, 496. The machine was capable of removing peel of 500 g of garlic segments in 1 minute giving the capacity of 15 kg/hr. The cost incurred was very less as compared to already available garlic peeling units.

Table 9: Feasibility testing with manual peeling

Specification	Manual peeling	Machine peeling
Quantity of material processed	150 kg	150 kg
Peeling rate	1 kg/hr	15kg/hr
Time required	150/1 =150 hrs	150/15 =10 hrs
Labor charges	Rs. 30/ hr (Unskilled)	Rs. 40/hr (Skilled)
Total cost incurred	Rs. 30 × 150 = Rs. 4500	Rs. 40× 10 = Rs. 400
Power consumption	----------	1.2 units/ hr Total units consumed in 10 hrs = 12 Cost of 1 units = Rs. 8 Total cost = Rs.96
Maintenance charges	----------	Rs. 500
Total cost	Rs. 4500	Rs. 996
Operating cost/kg	Rs 30	Rs. 6.64 ≈ Rs.7

Sensory evaluation of peeled samples

Samples were evaluated for the damage to peeled cloves in terms of visual inspection done and rated as per the hedonic scale. The best results were found for the samples peeled at lower rpm's of roller as compared to higher speed as an increase in the roller speed resulted in more abrasion of skin and thus affected the visual appearance of peeled samples.

Table 10: Visual appearance ratings of peeled samples

Roller speed	Pretreatment	Average hedonic scale rating
300	Control	4.331
	Hot air	4.291
400	Control	3.998
	Hot air	4.499
500	Control	4.330
	Hot air	3.166

Conclusion

The developed small capacity garlic peeler (15kg/hr) is found technically efficient and economically viable for peeling garlic cloves. From 1000g, approximately 500g is peeled off in one pass. The samples were also visually acceptable in terms of maintaining whole garlic segments. Economic analysis indicated the profitability with low operating cost per kg as compared to manual peeling process. Thus, this machine is capable of serving at small scale and small garlic processing and paste making units to enhance the income of self supported small entrepreneurs.

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