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An Scientific Approach of Design and Development of a Garlic Peeling Machine

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Abstract: Garlic, a species of bulbous flowering plant commonly eaten fresh, can be processed into a wide variety of products. One of these is peeled garlic, which is gaining in popularity among consumers as it offers convenience to many who wish to escape the hassle of garlic peeling. Therefore, the objectives of the present study was to develop an affordable garlic peeling machine that could efficiently increase processing capacity and reduce processing time as well as to assess its operational performance. To that end, a garlic peeling machine with the dimensions of 50 cm in width, 50 cm in length, and 85 cm in height was constructed that comprised a base, a tank having a diameter of 26 cm and a height of 35 cm which was lined with a durable rubber sheet, and a garlic peeling propeller. Installed under the tank to drive the propeller was a 3-phase electric motor. The material used to measure the efficiency of the machine was Chinese garlic bulbs weighing 200 and 300 g with a moisture content (wet basis) of 64.31%, and the machine efficiency was evaluated across the motor speeds of 450, 550, and 650 rpm and the processing intervals of of 10, 20, and 30 s. The results showed that no matter whether the test material weighed 200 or 300 g, the highest peeled garlic yield was obtained with the motor speed of 650 rpm and the processing interval of 20 s with the weight of intact garlic and damaged garlic combined standing at 179.5 g, or 89.76% of the total garlic weight, and 230.86 g, or 76.95% of the total garlic weight, respectively. In comparison, no matter whether the test material weighed 200 or 300 g, the highest intact garlic yield was achieved with the motor speed of 650 rpm and the processing interval of 10 s with the weight of intact garlic equaling 81.28 g, or 40.64% of the total garlic weight, and 53.56 g, or 17.85% of the total garlic weight, respectively.

Keywords: *Garlic peeling machine, Garlic peel, Garlic skin*

1. Introduction

Garlic, scientifically referred to as Allium sativum Linn., is a biennial plant with underground bulbs, each of which comprises 4-15 interlocking cloves, except the single-clove species called pearl garlic. Each clove is enclosed in thin pinkish white membranous skin. Garlic has rather short roots and long, flat leaves with sharp, narrow tips. It is also characterized by its inflorescences featuring white shoots, strong aroma, and hot flavor [1].

Garlic is not only consumed fresh due to its pleasant flavor and texture but also used to season a wide array of dishes because of its ability to enhance taste. In addition, it is processed into supplements in the forms of capsules or tablets, taken by health-conscious consumers across the world.

This bulbous flowering plant is widely grown in Northern and Northeastern Thailand since its growth is promoted by the cold weather in those regions. However, garlic may be cultivated in any regions having a relatively mild weather and suitable soil properties, such as fertile soil with a right combination of clay and sand containing humus and permitting water flow [2]. According to the Office of gricultural Economics [3] statistics, garlic was cultivated across approximately 69,140 rais of land all over Thailand, producing over 75,444 tons of yields. Additionally, in 2021, 50,312.54 tons of garlic were imported, and 2,430 tons were exported, with the values reaching THB1,032.98 million and THB116.70 million, respectively.

Also, it was found that a worker was able to peel a mere 10 kg of garlic per 5-6 h, or 2 kg per h as the process was tedious, involving the use of a sharp knife to remove the skin of each clove.

Despite agreeing on the benefits of mechanical peeling in terms of increased yields, most studies along this line are hindered by mixed results with respect to yield quality. For instance, Chirattiyangkur and Mongkolthalaeng [6] constructed a manual garlic peeling machine with the dimensions of 310 mm in width, 400 mm in length, and 420 mm in height operating with the friction between 2 rubber sheets measuring 40H in hardness level. According to their findings, when the rubber sheets were set 20 mm apart, the invention could peel 100 g of Chinese garlic in 4 min comprising 86.18% intact yield and 10.34% damaged yield. In contrast, when they were positioned 9 mm apart, the machine was able to remove the membrane of 100 g of Thai garlic in 4 min, but the yield was only 52.70% intact and 26.35% damaged.

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Kaewka and Srichart [7] developed a cylindrical garlic peeler 30 cm in height and 20 cm in diameter using circulating air pressure equipped with a 0.5 cm air inlet and 3.8 cm air outlet. Evaluated across different air pressure levels, processing intervals, and garlic volumes, the peeler was shown to be most efficient with the yield of 35.32 kg per h or 98.11% when the air pressure was set to 8 bar, the processing interval lasted for 30 s, and the material tested weighed 300 g.

Manjunatha, et al. [8] created a cylindrical garlic peeling machine covered with a 10 mm thick rubber sheet assessed across several parameters, namely cylinder speed (29, 36, and 42 rpm), cylinder-concave clearance (8, 10, and 12 mm), moisture content (23.1%, 27.7%, 33.4%, and 40.5% wet basis, and concave mechanism. It was found that the performance of the machine was maximized with the cylinder speed of 36 rpm and the cylinder-concave clearance of 10 mm, contributing to the peeling efficiency, peeled yield, unpeeled yield, damaged yield, and peel separation of 86.6%, 86.2%, 4.7%, 9.15%, and 96%, respectively. Additionally, the use of the invention to peel every 1 kg of garlic would save 16.11 rupees of processing costs and 1.63 h of processing time, or 94.99% and 97%, respectively.

Finally, Singh, et al. [9] built a rotary disc type garlic clove peeling machine that was compact, portable, and applicable in various industries ranging from large restaurants to hotels. A test on garlic with a moisture content (wet basis) of 41.69% indicated that this US$137 peeler could reach the removal rate of as high as 89.43%.

A closer look at the aforementioned literature also reveals that the production costs of most, if not all, peeling technologies remain an issue of concern. Thus, mechanical peelers are not easy to acquire, particularly among small farmers and entrepreneurs. Therefore, the present study aimed to develop a garlic peeling machine that was not only affordable but also efficient in terms of processing capacity and processing time. Specifically, the objectives of the research were to:

- Design and develop an affordable and efficient garlic peeling machine for small farmers and entrepreneurs.
- Evaluate the efficiency of the garlic peeling machine in order to ensure its operational performance in real-life applications.

2. Methodology

Design and development of the garlic peeling machine

The dimensions of the machine were 50 cm in width, 50 cm in length, and 85 cm in height. It comprised three main components, namely a base, a garlic peeling propeller, and a 3-phase, ¼ horsepower electric motor. The base was made from 1”X1” steel tubes constructed into a square shape 50 cm in width, 50 cm in length, and 50 cm in height. A stainless tank was placed on the base that was lined with a durable rubber sheet having a diameter of 26 cm and a height of 35 cm built from a stainless sheet 1 mm in thickness, 35 cm in width, and 81.68 cm in length. Installed inside and under the tank were the garlic peeling propeller and the electric motor, respectively. The details of the prototype are displayed in Figure 1

Operation of the garlic peeling machine

Once the garlic peeling machine was started, the motor served to drive the garlic peeling propeller to both remove the skin and produce an upward wind blowing it out of the tank. After being run for predetermined period, the machine was switched off, and the material was brought out of the tank for separation into intact and damaged garlic as well as the identification and removal of the remaining skin.

Assessment of the efficiency of the garlic peeling machine

The machine efficiency was measured across the motor speeds of 450, 500, and 650 rpm and the processing intervals of 10, 20, and 30 s. The test material was Chinese garlic bulbs with a moisture content (wet basis) of 64.31% weighing 200 and 300 g. The evaluation of each of the parameters was repeated three times before the values were averaged. Then the percentage of damaged garlic was determined according to Equation (1).

$$weight\ damaged\ (\%) = \frac{\text{damaged garlic weight (g)}}{\text{total garlic weight (g)}} \times 100 \quad (1)$$

Also, the percentage of intact or slightly damaged garlic was calculated according to Equation (2).

$$weight\ intact\ (\%) = \frac{\text{intact garlic weight (g)}}{\text{total garlic weight (g)}} \times 100 \quad (2)$$

Additionally, the percentage of unpeeled or slightly peeled garlic was derived from Equation (3).

$$weight\ unpeeled\ (\%) = \frac{\text{unpeeled garlic weight (g)}}{\text{total garlic weight (g)}} \times 100 \quad (3)$$

In addition, the percentage of peeled or mostly peeled garlic was obtained from Equation (4).

$$weight\ peeled\ (\%) = \frac{\text{peeled garlic weight (g)}}{\text{total garlic weight (g)}} \times 100 \quad (4)$$

Then the final weight loss was calculated using the previously determined values according to Equation (5).

$$weight\ lost\ (\%) = [total\ garlic\ weight\ (g) - damaged\ garlic\ weight\ (g) - intact\ garlic\ weight\ (g) - unpeeled\ garlic\ weight\ (g) - peeled\ garlic\ weight\ (g)] \div \text{total garlic weight (g)} \times 100 \quad (5)$$

Whereby weight lost (%) is the percentage of lost garlic cloves from the peeling process

lost garlic weight (g) is the weight of lost garlic cloves from the peeling process

weight damaged (%) is the percentage of damaged garlic cloves from the peeling process

damaged garlic weight (g) is the weight of damaged garlic cloves from the peeling process

weight intact (%) is the percentage of intact garlic cloves from the peeling process

intact garlic weight (g)is the weight of intact garlic cloves from the peeling process

weight unpeeled (%) is the percentage of unpeeled or slightly peeled garlic cloves from the peeling process

unpeeled garlic weight (g) is the weight of unpeeled or slightly peeled garlic cloves from the peeling process

weight peeled (%) is the percentage of peeled or mostly peeled garlic cloves from the peeling process

peeled garlic weight (g) is the weight of peeled or mostly peeled garlic cloves from the peeling process.

Garlic clove condition

The condition of the garlic in various experimental stages was depicted in Figure 2

3. Results

The assessment of the efficiency of the garlic peeling machine developed across different material weight measurements, motor speeds, and processing intervals. According to the findings, when the garlic weighed 200 g, the motor speed was 650 rpm, and the processing interval was 10 s, the amount of intact garlic was the highest at 81.28 g or 40.64% with the volume of damaged garlic standing at 58.58 g or 29.29%, the volume of unpeeled garlic at 55.11 g or 27.56%, the volume of peeled garlic skin at 3.35 g or 1.67%, and the volume of lost garlic at 1.69 g or 0.84%.

Evidently, different assessment parameters contributed to outcome discrepancies. For instance, the material weight of 200 g, the motor speed of 550 rpm, and the processing interval of 30 s would cause up to 87.68% damaged garlic, while the volume of unpeeled garlic would reach 90.85% when the material weight was 300 g, the motor speed was 450 rpm, and the processing interval was 10 s. In contrast, the lost garlic would remain as low as 0.67% with the material weight of 200 g, the motor speed of 450 rpm, and the processing interval of 30 s. The findings are illustrated in Table 1.

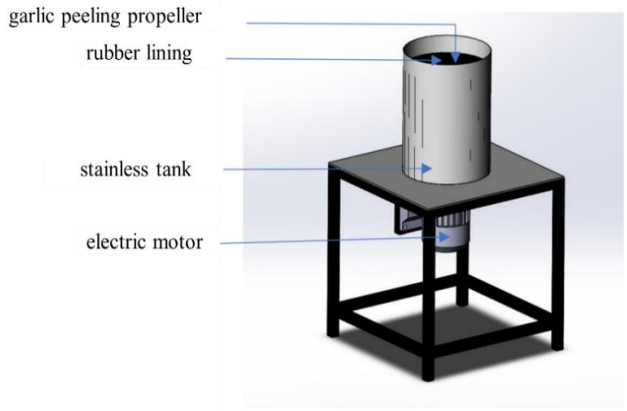

Fig. 1- Design of the garlic peeling machine prototype

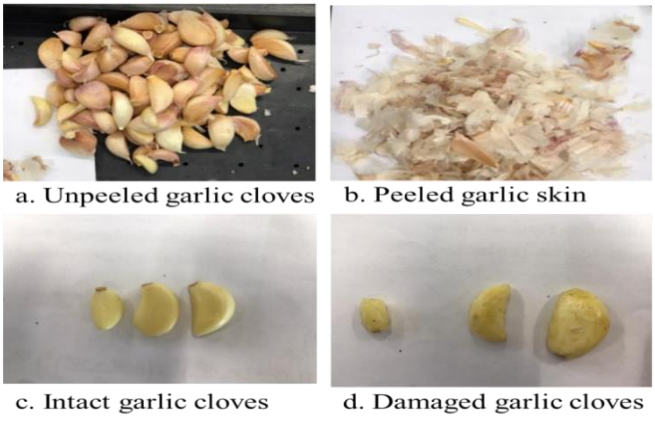

Fig 2- Garlic cloves.

4. Conclusion

The present study aimed to construct an affordable yet efficient garlic peeling machine accessible to small farmers and entrepreneurs. The findings indicated that the invention would achieve the best yield, i.e. the highest volume of intact peeled garlic, when it was set to a higher motor speed but a shorter processing interval. More importantly, it was able to peel a substantial amount of garlic with only a low percentage of garlic loss. Due to its efficiency as a garlic peeling machine, the prototype should be suitable for future commercialization.

5. Recommendations

6.1 In the use of a garlic peeling machine, the parameters involving material weight, motor speed, and processing interval need to be carefully configured in order to ensure peeling efficiency, minimize damage and loss, and thus optimize yields.

6.2 Further experiments to improve the design and efficiency of a garlic peeling machine should take into consideration the materials for lining the tank and creating the propeller, including those coming into close contact with or exerting force on the material, to ensure that the damage and loss from the peeling process will not exceed an acceptable level.

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Table 1 Efficiency of the garlic peeling machine as indicated by the test parameters.

Test material weight (g)	Test motor speed (rpm)	Test processing interval (s)	Intact garlic cloves		Damaged garlic cloves		Unpeeled garlic cloves		Peeled garlic skin		Lost garlic cloves	
			(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)
200	450	10	20.37	10.18	1.36	0.68	175.10	87.55	1.31	0.66	1.84	0.92
		20	33.01	16.51	20.23	10.11	140.48	70.24	3.43	1.71	2.86	1.43
		30	52.37	26.18	98.38	40.19	43.74	21.87	4.17	2.08	1.35	0.67
	550	10	67.20	33.60	23.57	11.79	100.20	50.10	3.89	1.94	5.13	2.57
		20	67.83	33.92	78.77	39.39	46.95	23.47	3.72	1.86	2.73	1.37
		30	8.05	4.02	175.35	87.68	4.76	2.38	5.58	2.79	6.27	3.13
	650	10	81.28	40.64	58.58	29.29	55.11	27.56	3.35	1.67	1.69	0.84
		20	10.91	5.46	168.59	84.30	10.67	5.34	4.98	2.49	4.84	2.42
		30	0.40	0.20	174.06	87.03	14.19	7.10	5.22	2.61	6.13	3.06
300	450	10	16.50	5.50	2.98	0.99	272.56	90.85	3.30	1.10	4.67	1.56
		20	32.87	10.96	44.26	14.75	215.04	71.682	3.92	1.30	3.91	1.30
		30	12.66	4.22	180.13	60.04	91.85	30.62	6.96	2.32	8.41	2.80
	550	10	45.79	15.26	63.57	21.19	181.97	60.66	3.23	1.08	5.44	1.81
		20	30.32	10.11	140.89	46.96	118.62	39.54	4.63	1.54	5.54	1.85
		30	12.39	4.13	215.52	71.84	57.57	19.19	7.84	2.61	6.68	2.23
	650	10	53.56	17.85	143.57	47.86	91.69	30.56	7.03	2.34	4.15	1.38
		20	28.26	9.42	202.60	67.53	55.36	18.45	7.74	2.58	6.04	2.02
		30	16.32	5.44	205.78	68.60	66.97	22.32	6.28	2.09	4.64	1.55