



Performance Evaluation of an Integrated Onion Peeling and Slicing Machine for Improving Processing Efficiency

Toni Okviyanto^{1*}, Firdaus¹, Muhammad Rizky Tolusha Putra¹, Patli Rahmanda¹, Stevan Juliandro Aruan¹.

¹ Department of Mechanical Engineering, Sriwijaya State Polytechnic, South Sumatra, 30128, Indonesia

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CORRESPONDING AUTHOR

*E-mail: toni.okviyanto@polsri.ac.id

A B S T R A C T

Onion processing at small- and medium-scale levels still faces challenges because peeling and slicing are generally performed as separate operations, resulting in longer processing times and greater material-handling requirements. This study aimed to develop and evaluate an integrated onion peeling and slicing machine that combines both processes into a single operating system powered by one prime mover. The study used an experimental engineering design approach, including a literature review, technical requirement identification, machine design, component fabrication, assembly, functional testing, and performance evaluation. The evaluated parameters included peeling efficiency, processing time, production capacity, and slicing quality. The results showed that, during peeling with a 5 kg material load at 1800 rpm, the machine achieved a peeling efficiency of 95.24% with a processing time of 15 min. During slicing with a 5 kg material load at 2800 rpm, increasing the number of blades from two to four reduced processing time from 3.00 to 1.50 min and increased production capacity from 100.00 to 200.00 kg/h. Slice thickness was targeted at approximately 1.5–2.0 mm, with the two-blade configuration providing the most visually uniform slices. Four blades produced the highest production capacity, whereas two blades produced more uniform slices. The results show that the integrated onion peeling and slicing machine can improve onion processing efficiency for small- and medium-scale applications, with blade configuration selection depending on the priority between production productivity and slicing quality.

Contribution to Sustainable Development Goals (SDGs):

SDG 9: Industry, Innovation & Infrastructure

1. INTRODUCTION

1.1. Research Background

Onion (*Allium cepa* L.) is one of the most widely consumed horticultural commodities worldwide and plays an important role in the food processing industry as a basic ingredient in various food products [1], [2], [3]. The increasing demand for processed onion products has encouraged the development of efficient post-harvest handling and processing technologies. However, conventional onion processing activities, particularly peeling and

slicing, are still predominantly performed manually in many small- and medium-scale food industries. Manual processing requires considerable labour, involves repetitive movements, and produces inconsistent product quality due to variations in peeling losses, slice thickness, and processing time [4], [5], [6], [7].

The peeling and slicing stages are critical processes in onion preparation because they directly influence production efficiency, product quality, and operational costs [8], [9]. Traditional manual peeling is time-consuming and may cause worker discomfort because exposure to volatile sulfur compounds released from onion tissues can irritate the eyes and reduce operator productivity [10]. Similarly, manual slicing often produces non-



uniform slice dimensions, affecting drying characteristics, cooking performance, and product appearance. Therefore, implementing mechanised processing systems that integrate multiple operations into a single unit has become an important approach to improve productivity and reduce dependence on manual labour [11], [12], [13].

Several studies have investigated mechanical onion processing technologies, including automated peeling systems, cutting mechanisms, and integrated food processing equipment [6], [14]. However, many existing machines are designed for a single operation, requiring separate equipment and additional handling between peeling and slicing processes. This approach increases processing time, energy consumption, equipment investment, and the risk of contamination during product transfer [15], [16]. An integrated onion peeling and slicing machine offers a potential solution by combining two essential processing stages into one continuous operation, thereby improving workflow efficiency and minimizing post-processing handling [17].

Despite these developments, the performance evaluation of integrated onion processing machines remains limited, particularly regarding operational parameters such as processing capacity, peeling efficiency, slicing efficiency, product loss, energy consumption, and overall processing effectiveness. Comprehensive evaluation is required to determine the feasibility of such equipment for small- and medium-scale food processing applications [18], [19], [20]. Furthermore, understanding the relationship between machine operating parameters and product quality characteristics is essential for optimizing machine performance [21], [22].

Therefore, this study aims to evaluate the performance of an integrated onion peeling and slicing machine by analyzing its processing capacity, peeling and slicing efficiency, material losses, and operational effectiveness. The results are expected to provide valuable insights into developing efficient onion processing technology and contribute to improving productivity, reducing labour requirements, and supporting the modernisation of food processing industries.

The developed machine is intended for potential application in small- and medium-scale onion-processing enterprises. However, this study focuses on the machine's engineering development and performance evaluation under controlled laboratory and workshop conditions.

1.2. Literature Review

The development of mechanical systems for agricultural and food processing applications has become an important research area due to the increasing demand for efficient, hygienic, and consistent production processes. In the onion processing industry, peeling and slicing are considered critical operations because they significantly affect processing time, product quality, labor requirements, and production costs. Conventional manual processing methods are labour-intensive and often result in inconsistent peeling quality and non-uniform slicing dimensions. Therefore, various studies have focused on developing mechanized solutions to improve the efficiency of onion post-harvest processing [23], [24].

Previous studies on onion peeling machines have mainly focused on improving peeling efficiency through different mechanical mechanisms. Hegazy et al. developed an onion peeling machine for small-scale agricultural industries by combining a rotary cutting mechanism and peeling drum system

[25]. The machine performance was evaluated based on productivity, peeling efficiency, peeling losses, product damage, power requirement, and operational cost [26]. The study reported that machine operating parameters, onion size, and peeling mechanism significantly influenced the overall peeling performance. These findings indicate that optimization of mechanical interaction between the onion surface and peeling components is essential to minimize product losses while maintaining high processing capacity [19], [27].

Recent developments have introduced more automated peeling approaches using sensor-based and controlled mechanical systems. A smart automated onion skin peeling machine utilizing a parallel roller mechanism was developed to improve peeling consistency and reduce manual intervention [28]. The system incorporated monitoring components to evaluate operational conditions and improve processing reliability, demonstrating the potential of automation in small- and medium-scale onion processing applications [28], [29]. Similarly, appropriate technology-based peeling machines for shallots have been developed to address productivity limitations in household industries. The performance evaluation showed that mechanical peeling systems can reduce operator workload and increase processing capacity compared with conventional methods [30], [31].

In addition to peeling processes, slicing technology has also received considerable attention because slice uniformity influences further processing stages such as drying, frying, and packaging [32]. The performance of vegetable slicing machines is generally evaluated based on throughput capacity, slicing efficiency, cutting quality, and product damage. A vegetable slicing machine evaluated for onion bulbs and other agricultural products demonstrated that cutting speed and material characteristics affected slicing efficiency and processing capacity [33]. Therefore, the design of cutting mechanisms, blade geometry, and operational parameters plays an important role in achieving consistent slice quality [25], [34].

Several researchers have attempted to integrate multiple processing operations into a single machine to improve workflow efficiency. Researchers developed an integrated onion peeling and slicing machine to combine peeling and cutting operations in one processing unit. The integration approach provides advantages by reducing material transfer time, minimizing processing space requirements, and improving production continuity [33]. Evaluations of such integrated systems show that combining peeling and slicing can achieve acceptable efficiency while reducing the need for separate machines. Furthermore, recent research on vegetable processing automation demonstrates a growing trend toward intelligent and integrated systems capable of improving accuracy, productivity, and operational control [35], [36].

Recent studies have investigated various mechanical approaches to improve onion processing operations. Maghfurah et al. developed an onion epidermis peeling machine using a rubber-friction mechanism [1], while investigated a rotary-blade onion slicing machine. Bochat et al. examined the cutting behavior of onion outer layers, providing evidence of the importance of cutting characteristics in the design of onion-processing mechanisms [5]. Kate et al. developed an onion bulb descaler for removing and collecting surface dry peel [23], while evaluated mechanical equipment for onion handling and processing. More recently, Ulum et al. developed a portable

prototype integrating onion peeling, cutting, and grinding functions [37], and Zastempowski et al. investigated energy consumption during material cutting in onion peeling [38]. Saputra et al. further reported that blade number affects power requirements and processing time in onion slicing operations [21].

Although these studies provide important information on individual onion-processing mechanisms, further engineering evaluation is required for integrated peeling and slicing systems operated within a single machine. In particular, the relationship between blade configuration, processing time, production capacity, and slicing quality requires further evaluation. This study therefore focuses on the controlled performance evaluation of an integrated onion peeling and slicing machine using quantitative operational indicators.

Although previous studies have demonstrated the effectiveness of individual peeling and slicing mechanisms, most investigations have focused on evaluating a single processing stage. Limited studies have comprehensively analyzed the performance of integrated onion peeling and slicing machines, particularly in terms of processing capacity, peeling efficiency, slicing efficiency, product losses, and overall operational effectiveness. A comprehensive performance evaluation is necessary to determine whether an integrated system can provide significant improvements compared with conventional processing methods [2], [3], [39].

Based on the reviewed literature, the present study focuses on the performance evaluation of an integrated onion peeling and slicing machine by analyzing key operational parameters. The research contributes by providing a systematic assessment of an integrated processing system that combines two essential onion preparation stages into a single machine. The findings are expected to support the development of efficient food processing equipment, particularly for small- and medium-scale industries requiring compact, productive, and cost-effective processing solutions [40], [41].

1.3. Research Objective

This study aims to evaluate the performance of an integrated onion peeling and slicing machine to improve processing efficiency and determine its feasibility for food processing applications. The research focuses on analyzing the operational performance of the machine based on processing capacity, processing time, and productivity, as well as evaluating peeling performance through peeling efficiency, peeling losses, and the quality of peeled onions. Furthermore, the study assesses slicing performance based on slicing efficiency, slice uniformity, product damage, and the quality of sliced onion products. This study also aims to determine the overall effectiveness of the integrated system by evaluating the combined peeling and slicing process and identifying how operational parameters affect machine performance. The findings of this research are expected to provide technical information to support the development and potential transfer of efficient onion processing equipment, particularly for small- and medium-scale food industries, by reducing labor requirements, increasing processing productivity, and improving the consistency of processed onion products. The technical performance data obtained in this study are also expected to provide a basis for subsequent field implementation and assessment of technology adoption and socio-economic benefits among potential users.

2. MATERIALS AND METHODS

2.1. Research Design

This study employed an experimental approach combined with an engineering design methodology to develop and evaluate an integrated shallot peeling and slicing machine. The research followed several stages, including a literature review, identification of technical requirements, conceptual and mechanical design, component fabrication, assembly, functional testing, and performance evaluation. The developed machine integrates the peeling and slicing processes into a single operating system powered by a common power source. The research design aimed to evaluate the machine's technical performance and determine the operating parameters that provide optimal processing performance.

The performance evaluation focused on production capacity, peeling efficiency, slice thickness uniformity, product damage rate, energy consumption, and overall machine operational performance. An experimental approach was selected to obtain quantitative data under controlled operating conditions. The study was conducted at the Production Workshop, Department of Mechanical Engineering, Politeknik Negeri Sriwijaya.

Figure 1 illustrates the overall research procedure. The experimental procedure consisted of literature review and problem identification, preparation of materials and equipment, machine inspection and test preparation, functional testing, peeling and slicing process trials, data collection, data analysis, and performance evaluation. The peeling and slicing tests were conducted separately to evaluate the operational performance of each processing unit, while the results were subsequently analyzed to determine the overall processing efficiency of the integrated machine.

As shown in Figure 1, the research procedure systematically evaluated the integrated machine's functional and operational performance. The evaluation focused on peeling efficiency and peeling processing time, while the slicing process was assessed based on blade configuration, processing time, production capacity, and slice uniformity.

2.2. Machine Design and Operating Principle

The developed machine integrates peeling and slicing systems. The main components include the machine frame, electric motor, power transmission system, peeling chamber, peeling mechanism, slicing chamber, rotary blade assembly, material-feeding mechanism, and product-discharge chute.

Figure 2 shows the design and fabricated prototype of the integrated shallot peeling and slicing machine. The figure illustrates the overall machine configuration and the arrangement of the main components, including the frame, electric motor, transmission system, peeling unit, slicing unit, feeding mechanism, and product discharge chute.

The machine transmits mechanical power from a single prime mover through the transmission system to the peeling and slicing mechanisms. Fresh shallots are initially fed into the peeling chamber, where the outer skin is mechanically removed. The peeled shallots are then directed to the slicing unit, where a rotary blade assembly cuts the material into slices with a predetermined thickness.

The integration of the two processing operations is intended to minimize material handling between processes, reduce the

number of processing stages, and improve the overall efficiency of shallot processing. The machine design also considers ease of operation and maintenance, compact construction, and suitability for small- and medium-scale food-processing enterprises

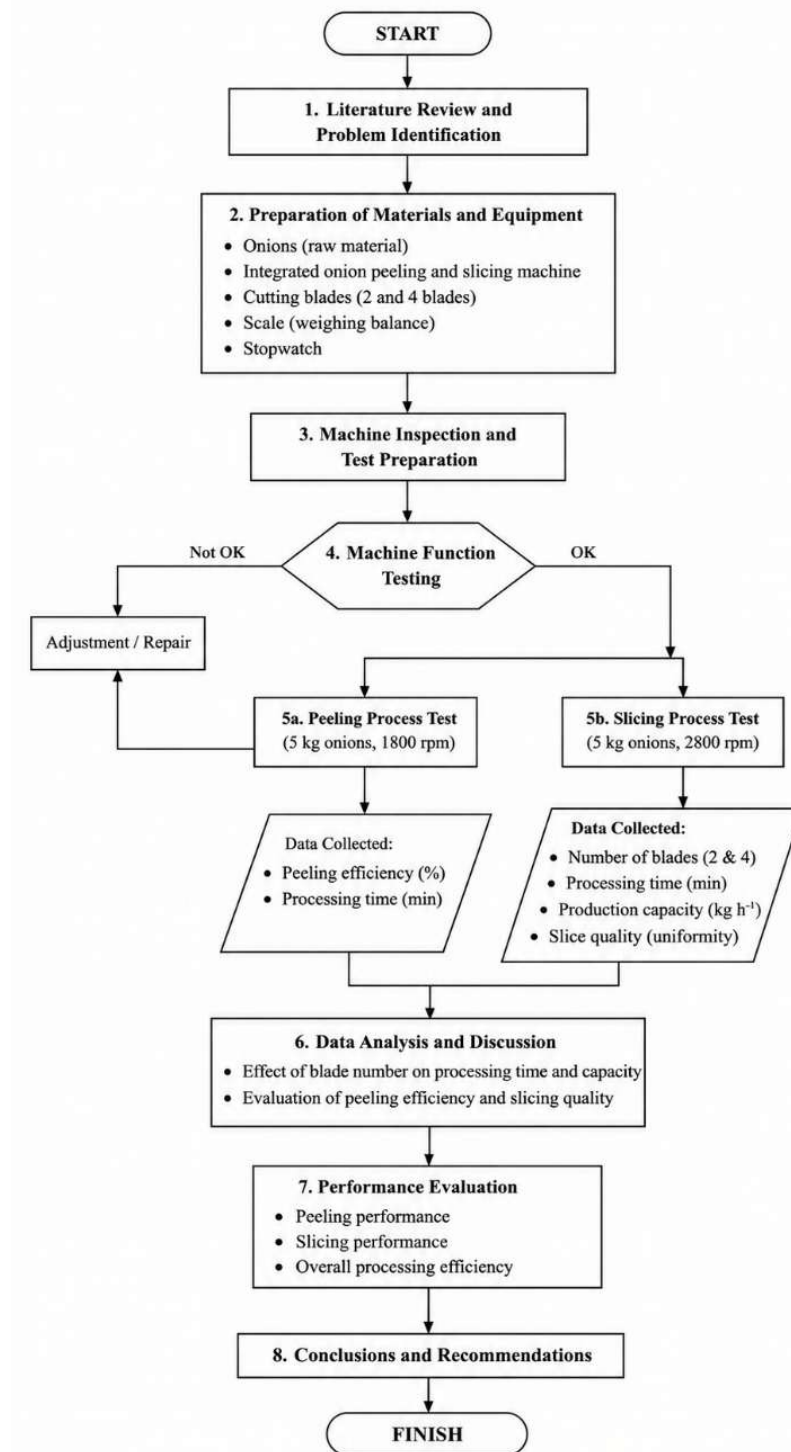


Fig. 1. Research flowchart for the performance evaluation of the integrated onion peeling and slicing machine



Fig. 2. Design and fabricated prototype of the integrated shallot peeling and slicing machine: (a) three-dimensional design, and (b) fabricated machine.

2.3. Materials and Equipment

The primary material used in this study was fresh shallot (*Allium cepa* var. *aggregatum*) with relatively uniform size and quality. The raw materials were sorted prior to testing to remove damaged, rotten, or otherwise unsuitable shallots. The use of relatively uniform raw materials was intended to minimize variability in the experimental results.

The main equipment consisted of the integrated shallot peeling and slicing machine, an electric motor as the prime mover, a power transmission system comprising pulleys and belts, rotary slicing blades, a tachometer for measuring rotational speed, a digital balance for measuring material mass, a stopwatch for recording processing time, and a vernier caliper or thickness gauge for measuring slice thickness. Additional supporting tools were used for machine adjustment, setup, and routine maintenance.

2.4. Research Variables and Experimental Parameters

The independent variables in this study consisted of machine operating parameters, particularly rotational speed and blade configuration. The rotational speed was varied according to the experimental design, while the blade configuration was varied based on the number and/or geometry of the blades installed in the machine.

The dependent variables represented the machine performance and included:

- production capacity (kg/h);
- peeling efficiency (%);
- slice thickness uniformity (mm);
- percentage of damaged products (%);
- energy consumption; and
- overall machine operational performance.

The controlled variables included the type and quality of shallots, initial material mass, testing duration, machine operating conditions, ambient conditions, and operator. Controlling these

variables was intended to ensure that variations in the measured responses were primarily attributable to the operating parameters under investigation. The research proposal identified rotational speed and blade configuration as the primary independent variables, while production capacity, peeling efficiency, slice thickness, and product damage served as the main performance indicators.

2.5. Experimental Procedure

Before testing, the machine was inspected to ensure that all mechanical components, transmission elements, rotary blade assembly, and safety components were properly installed and functioning correctly. The machine rotational speed was measured using a tachometer and adjusted according to the experimental treatment. The experimental tests were conducted under controlled laboratory and workshop conditions to evaluate the engineering performance of the developed integrated onion peeling and slicing machine.

The shallots were first sorted and weighed to determine the initial material mass. A predetermined quantity of shallots was then fed into the peeling unit. After peeling, we collected and weighed the material to determine the post-peeling mass and the mass difference. We then calculated peeling efficiency from the initial and post-peeling masses. For the slicing test, the peeled shallots were fed into the slicing mechanism using the specified rotary blade configuration. We recorded processing time with a stopwatch for each experimental treatment. The slicing tests used two-, three-, and four-blade configurations to evaluate the effect of blade number on processing time and calculated production capacity.

After each test, we collected the processed material and separated it into the relevant output categories. We recorded the mass of the processed material and the processing time for subsequent performance calculations. We evaluated slicing quality by visually assessing slice uniformity. We performed each experimental treatment according to the available experimental data and operating conditions. The performance analysis focused on measurable engineering parameters, including peeling efficiency, mass difference, processing time, production capacity, and visual slicing uniformity.

2.6. Performance Evaluation

2.6.1. Production Capacity

Production capacity was determined based on the mass of shallots processed and the processing time, as follows:

$$Q = \frac{m}{t}$$

where (Q) is the production capacity (kg/h), (m) is the mass of shallots processed (kg), and (t) is the processing time (h).

2.6.2. Peeling Efficiency

Peeling efficiency was determined as the ratio of the mass of successfully peeled shallots to the initial mass of the raw material, as follows:

$$\eta_p = \frac{m_p}{m_0} \times 100\%$$

where η_p is the peeling efficiency (%), m_p is the mass of successfully peeled shallots (kg), and m_0 is the initial mass of shallots (kg).

2.6.3. Slice Thickness Uniformity

Slice thickness uniformity was evaluated by measuring the thickness of individual shallot slices at several randomly selected points. The mean slice thickness and thickness variation were subsequently determined. Lower thickness variation indicated greater uniformity of the slicing results. Slice thickness uniformity was assessed based on the deviation of individual slice thicknesses from the mean value.

2.6.4. Percentage of Damaged Products Capacity

The percentage of damaged products was calculated as the ratio of the mass of damaged shallot slices to the total mass of processed material, as follows:

$$D = \frac{m_d}{m_t} \times 100\%$$

where (D) is the percentage of damaged products (%), m_d is the mass of damaged shallot slices (kg), and m_t is the total mass of processed material (kg).

2.7. Data Analysis

The experimental data were analyzed quantitatively using descriptive and comparative analyses. The measured performance parameters were presented as mean values and compared across the experimental treatments.

The effects of rotational speed and blade configuration on machine performance were evaluated by examining the relationships between the independent and dependent variables. The optimum operating condition was determined based on the treatment combination that provided the best overall performance, particularly high production capacity, high peeling efficiency, uniform slice thickness, low product damage, and efficient energy consumption.

2.8. Experimental Validation

The experimental analysis-derived optimum operating condition was subsequently validated through confirmation testing. The performance obtained under the optimum condition was compared with the predicted performance and/or the results of the initial experimental trials. The confirmation test assessed the reliability of the selected operating parameters and verified the developed machine's applicability and performance under the specified operating conditions.

3. RESULT AND DISCUSSION

3.1. Results of the Development of the Shallot Peeling and Slicing Machine

The study produced a prototype of an integrated shallot peeling and slicing machine that combines two processing operations in a single system. The machine consists of a supporting frame, an electric motor as the prime mover, a pulley-and-belt transmission system, a peeling mechanism, and a slicing mechanism. The integration of the two mechanisms was designed to reduce

manual material handling, shorten processing stages, and improve overall shallot processing efficiency. Figure 2 shows the prototype of the developed machine, including the overall configuration and arrangement of the main components of the integrated peeling and slicing system.



Fig. 2. Prototype of the developed integrated shallot peeling and slicing machine.

The machine development process involved several stages, including design, component fabrication, assembly, functional testing, and performance evaluation. Functional testing showed that the main machine components, including the drive system, transmission system, peeling mechanism, and slicing mechanism, operated as intended. These preliminary test results provided the basis for further evaluation of machine performance in terms of production capacity, peeling efficiency, processing time, and slicing quality.

3.2. Results of the Shallot Peeling Process

The peeling process was evaluated using 5 kg of shallots at 1,800 rpm. The peeling process took 15 min. After the peeling process, the mass of the peeled shallots was measured, while the mass loss was determined from the difference between the initial and final material masses.

Using Equation (2), the peeling efficiency was calculated. The results of the shallot peeling test are presented in Table 1.

Table 1. Results of the shallot peeling process

Parameter	Value
Rotational speed	1,800 rpm
Initial material mass	5 kg
Processing time	15 min
Mass after peeling	4.762 kg
Mass loss	0.238 kg
Peeling efficiency	95.24%*
Mass loss percentage	4.76%

Peeling efficiency indicates the peeling mechanism's ability to remove the outer skin from the processed shallots. The result shows that the peeling mechanism removed a substantial portion of the shallot skin under the tested operating conditions.

However, the peeling process resulted in a mass loss of 0.238 kg, equivalent to 4.76% of the initial material mass. This mass

loss may have originated from the removed shallot skin and portions of the edible material detached during mechanical peeling. This finding indicates that the peeling mechanism could be further improved, particularly through optimization of the contact force, frictional interaction, material residence time within the peeling chamber, and machine operating conditions.

The results further indicate that peeling efficiency is not solely determined by rotational speed but is also influenced by the physical characteristics of the raw material and the mechanical interaction between the shallots and the peeling components. Therefore, further development should focus on minimizing material loss while maintaining the ability of the machine to effectively remove the outer skin.

3.3. Results of the Shallot Slicing Process

The slicing process was evaluated using 5 kg of material at 2,800 rpm. The experimental treatments used three blade configurations: 2, 3, and 4 blades. Table 2 presents the slicing time recorded for each blade configuration.

Table 2. Effect of blade number on slicing time

Number of blades	Material mass (kg)	Slicing time (min)
2	5	3.00
3	5	2.25
4	5	1.50

The results show that increasing the number of blades reduced the slicing time. Two blades required 3.00 min, whereas three blades reduced the processing time to 2.25 min. Four blades produced the shortest processing time, 1.50 min.

The reduction in processing time can be attributed to the increased cutting frequency per unit time. At the same rotational speed, a greater number of blades provides more cutting events during each revolution of the blade disc. Consequently, the material can be processed more rapidly, resulting in a shorter overall slicing time.

These findings indicate that blade configuration is an important factor affecting slicing performance. Increasing the number of blades can improve processing speed; however, the resulting increase in cutting frequency should be considered together with slice quality, thickness uniformity, material flow, and cutting stability. An excessive number of blades may potentially increase the likelihood of irregular cutting or material accumulation if the feeding rate and blade geometry are not properly matched.

3.4. Effect of Blade Number on Production Capacity

Production capacity was calculated using Equation (1) as the ratio of processed material mass to processing time, expressed in hours. Table 3 presents the calculated production capacity for each blade configuration.

Table 3. Production capacity as a function of blade number

Number of blades	Material mass (kg)	Processing time (h)	Production capacity (kg/h)
2	5	0.0500	100.00
3	5	0.0375	133.33
4	5	0.0250	200.00

Production capacity increased as the blade number increased. Two blades produced 100.00 kg/h, while three blades increased capacity to 133.33 kg/h. Four blades produced the highest capacity, reaching 200.00 kg/h.

The increase in production capacity from 100.00 to 200.00 kg/h represents a 100% improvement compared with the two-blade configuration. This increase was directly associated with the reduction in slicing time. The shorter processing time allowed the machine to process more material within the same operating period.

From a mechanical perspective, increasing the number of blades increases the number of cutting interactions occurring during each revolution of the blade disc. At 2,800 rpm, this configuration increases the cutting frequency, allowing more material to be processed per unit time. Effect of Blade Number on Slice Quality

Slice quality is an important performance indicator for evaluating the developed shallot slicing mechanism because increasing production capacity should not compromise slice uniformity. Based on the experimental observations, the two-blade configuration produced the most uniform slices compared with the three- and four-blade configurations. This result indicates that the number of blades affects not only the processing rate but also the stability and consistency of the cutting process.

The visual appearance of the shallot slices obtained from the different blade configurations is presented in Figure 4. The figure directly compares the resulting slice characteristics for the two-, three-, and four-blade configurations. Differences are evident in slice shape, apparent thickness uniformity, and the occurrence of irregular slices. The two-blade configuration produced a relatively consistent slice appearance, whereas a greater proportion of non-uniform slices was observed as the number of blades increased.



Fig. 4. Visual appearance of shallot slices produced using different blade configurations: (a) 2 blades, (b) 3 blades, and (c) 4 blades.

Differences in slice quality can be attributed to changes in cutting frequency associated with the number of blades. At a constant rotational speed of 2,800 rpm, increasing the number of blades increases the number of cutting events per revolution. Although this condition improves the material processing rate, it also reduces the interval between successive cutting events. Consequently, the material may experience more frequent cutting interactions, which can affect material-feeding stability and the consistency of the cutting process.

The two-blade configuration provided a comparatively more stable cutting condition, allowing the material to enter the cutting zone with sufficient intervals between successive cutting events. This condition contributed to a more consistent cutting action and resulted in relatively uniform slices. In contrast, the three- and four-blade configurations increased cutting frequency and reduced slicing time, as shown in Table 2. However, the higher cutting frequency was accompanied by more irregular slices, indicating that improvements in processing capacity were associated with reduced slice uniformity.

The results demonstrate a trade-off between processing capacity and slice quality. The four-blade configuration achieved the highest production capacity of 200.00 kg/h, which was twice that obtained with the two-blade configuration. However, the two-blade configuration provided better visual uniformity of the sliced product. This finding indicates that increasing the number of blades improves throughput, but the resulting increase in cutting frequency must be balanced against product-quality requirements.

From an operational perspective, the blade configuration should therefore be based on the primary processing objective. The four-blade configuration is more suitable when high production throughput is the primary requirement, whereas the two-blade configuration is more appropriate when slice uniformity and product quality are prioritized. For applications requiring a balance between throughput and product quality, the three-blade configuration may provide an intermediate operating condition, although further quantitative evaluation of slice thickness variation and product damage is required to determine its suitability.

3.5. Machine Performance Evaluation Based on the Experimental Parameters

The overall performance of the developed machine was evaluated based on several key parameters, including peeling efficiency, processing time, production capacity, and slice quality. These parameters were considered collectively to assess the effectiveness of the integrated peeling and slicing system under the tested operating conditions.

During peeling, the machine processed 5 kg of shallots at 1,800 rpm in 15 min. The peeling efficiency was 90.48%, indicating that the peeling mechanism removed a substantial proportion of the outer skin. Nevertheless, a mass loss of 9.52% was observed, indicating that part of the processed material was lost during the peeling operation. This loss may be associated with removing the outer skin and detaching edible material during mechanical interaction within the peeling chamber.

For the slicing process, increasing the number of blades from two to four reduced the processing time from 3.00 to 1.50 min for 824 Okviyanto et al.

a 5 kg material load. The reduction in processing time consequently increased the calculated production capacity from 100.00 to 200.00 kg/h. This result demonstrates that increasing the number of blades can substantially improve machine throughput under a constant rotational speed of 2,800 rpm.

Although the four-blade configuration provided the highest production capacity, the two-blade configuration produced more uniform slices based on the experimental observations. This finding demonstrates that machine performance cannot be adequately assessed using production capacity alone. An increase in throughput may be accompanied by reduced product uniformity, indicating a performance trade-off between productivity and slice quality.

Therefore, determine the optimum operating condition by considering multiple performance indicators, including production capacity, peeling efficiency, slice thickness uniformity, product damage, and energy consumption. The relative importance of each parameter depends on the machine's intended application and primary processing objective. A comprehensive evaluation of these parameters is consequently required to identify the most appropriate operating condition for the integrated shallot peeling and slicing machine.

3.6. Analysis of the Optimum Operating Condition

Based on the experimental results obtained, the best operating condition in terms of production capacity was achieved at a rotational speed of 2,800 rpm with four blades. Under this condition, the machine processed 5 kg of shallots in 1.50 min, corresponding to a production capacity of 200.00 kg/h. This configuration represents the highest throughput among the blade configurations evaluated in this study.

However, when slice quality was considered, the two-blade configuration produced more uniform slices based on visual observations. This result indicates that the operating condition providing the highest productivity was not necessarily the condition providing the best product quality. The difference between these two performance outcomes confirms the trade-off between processing throughput and slice uniformity.

Accordingly, two operating conditions demonstrated different performance advantages. The four-blade configuration can be selected when maximizing production throughput is the primary objective, whereas the two-blade configuration is more appropriate when slice uniformity is the principal quality requirement. The three-blade configuration may provide an intermediate alternative; however, its suitability should be verified using quantitative quality indicators rather than visual assessment alone.

Determining the optimum operating condition requires integrating all relevant experimental responses. In particular, quantitative measurements of slice thickness uniformity, percentage of damaged products, and energy consumption should be incorporated into the optimization analysis.

3.7. Experimental Validation

Experimental validation compared the best-performing operating condition identified in the initial experimental trials with the results of a subsequent confirmation test. Based on the experimental data currently available, the highest production capacity was obtained using four blades at a rotational speed of

2,800 rpm. Under this condition, the machine processed 5 kg of shallots in 1.50 min, corresponding to a production capacity of 200.00 kg/h.

This operating condition was therefore selected as the reference condition for the confirmation test. The confirmation experiment should use the same material mass, rotational speed, and four-blade configuration as the initial test. Then compare the resulting production capacity and other relevant performance parameters with the corresponding values from the initial experiment to evaluate the consistency and repeatability of machine performance.

Confirmation testing is important for determining whether the observed performance can be reproduced under the same operating conditions rather than being attributable to experimental variability. A close agreement between the initial and confirmation-test results would provide evidence of the reliability and repeatability of the selected operating condition. The validation results can then support further performance testing and prototype development of the integrated shallot peeling and slicing machine.

4. CONCLUSION

The integrated shallot peeling and slicing machine was successfully developed and demonstrated functional performance by combining peeling and slicing operations within a single system powered by one prime mover. Under the tested conditions, the peeling process achieved 95.24% efficiency when processing 5 kg of shallots at 1,800 rpm for 15 min, with a mass loss of 4.76%. For slicing, increasing the blade number from two to four at 2,800 rpm reduced processing time from 3.00 to 1.50 min and increased production capacity from 100.00 to 200.00 kg/h. The four-blade configuration provided the highest production capacity, whereas the two-blade configuration produced more uniform slices, indicating a trade-off between processing productivity and slice quality. Overall, the developed machine shows potential for small- and medium-scale shallot processing, while further optimization is required to reduce material loss, improve slice uniformity, and validate its performance under optimum operating conditions

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