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Effectiveness Analysis of a Semi-Automatic Banana Chips Slicing Machine

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ABSTRACT

Bananas are one of the main plantation commodities in Pagerharjo Village, Samigaluh. The local women's farmer group (KWT) processes bananas into chips, but the manual production process creates obstacles because the slices are not uniform. This study aimed to determine the working mechanism of a semi-automatic banana chips slicing machine, identify the most effective test result, and compare production capacity between machine-assisted slicing and manual slicing. The research used a research and development (R&D) method implemented through observation, interviews, problem formulation, product needs analysis, machine performance testing, data collection, and data analysis. Experimental testing was conducted in three blade-gap variations to obtain the most effective slicing result. The machine used a 1/4 hp electric motor with a nominal speed of 1400 rpm. The most effective result was obtained at a 4 mm blade gap, which produced an average slice thickness of 3 mm, 747 g of slices meeting the standard shape from 1 kg of bananas, and a slicing capacity of 27 kg/h.

1 Introduction

Pagerharjo Village is one of the villages in Indonesia with diverse agricultural products and processed agricultural commodities that can help support national food needs. In Pagerharjo Village, 3,721 residents work in agriculture, fisheries, and livestock [1]. Based on the village profile, Pagerharjo has an area of 1,069.5115 ha. Its average temperature of 18-30 °C and rainfall of 2500-3000 mm make the land suitable for agriculture and plantations [2]. One of the plantation products in the village is banana.

According to Statistics Indonesia, banana production in the Special Region of Yogyakarta reached 68,257 t in 2021 [3]. A medium-sized banana contains 72.9 g of water, 108 kcal of energy, 1 g of protein, 0.8 g of fat, 1.9 g of fiber, and 9 mg of vitamin C [4]. These nutritional contents make bananas beneficial as an antihypertensive-supporting food, a source of carbohydrates and vitamins, a metabolism-supporting fruit, an immune-supporting food, and a mood food because bananas can stimulate serotonin formation in the brain [5].

The banana variety grown in Pagerharjo Village is raja nangka banana. A raja nangka banana tree can reach 3.5 m in height. The average fruit length is about 15 cm. One bunch generally consists of 7-8 hands, and each hand contains 14-24 bananas [6]. Raja nangka banana supports both the local economy and food needs. The harvested bananas can be sold directly or processed into food products. KWT Madu Lestari processes banana harvests into banana chips, which have considerable market demand and contribute to the local economy.

Based on observations and interviews with the head of KWT Madu Lestari, the banana chips production process still uses a manual slicer operated by two to three workers. This condition limits production efficiency and causes nonuniform slices. Previous studies have shown that slicing machines for home industries and agricultural products can improve processing efficiency and help standardize product dimensions [7], [8]. Therefore, a semi-automatic banana chips slicing machine was developed as an appropriate technology to overcome the production problem. The machine is expected to produce banana slices with shapes and sizes that meet the requirements of KWT Madu Lestari.

2 Method

This study used a research and development (R&D) method. The research began by identifying problems in Pagerharjo Village, followed by field observation, interviews with the head of KWT Madu Lestari, machine fabrication, and machine testing.

Data were collected using an experimental method by recording the results of several blade-gap variations. After slicing and measuring the slices, machine effectiveness was calculated by comparing the slicing results from each blade-gap variation. The slicing capacity produced by the machine was also calculated.

The blade-gap variations used in this study were 3 mm, 3.5 mm, and 4 mm. Each variation was used to slice 1 kg of raja nangka bananas until all samples were processed. Different blade gaps produced different slicing results. The time required to finish each 1 kg sample was measured using a stopwatch, and slice thickness was measured using a vernier caliper. The initial data collection plan is shown in Table 1.

Table 1. Data collection plan for blade-gap variation testing

No.	Trial	Blade gap (mm)	Standard shape (kg)	Non-standard shape (kg)	Slicing time
1	1	3			
2	2	3.5			
3	3	4			

The average slice thickness was obtained by taking 30 sliced samples, measuring their thickness, and calculating the mean value using (1).

$$\bar{x} = \frac{\Sigma x_i}{n} \quad (1)$$

where $\bar{x}$ is the average thickness, Σx_i is the total measured thickness, and n is the number of slices.

Machine capacity was calculated from the most effective slicing result. According to Rochmadi, the work capacity of a construction or processing machine can be expressed in kg/h or m^3/h, based on the production volume processed per unit time [9]. The machine capacity was calculated using (2).

$$Q = q \times N = q \times \frac{3600}{C_m} \quad (2)$$

where Q is hourly production capacity (kg/h or m^3/h), q is production per cycle (kg or m^3), N is the number of cycles per hour, and C_m is the cycle time in seconds or minutes.

3 Result and discussion

3.1 Machine design

The semi-automatic banana chips slicing machine was designed using Autodesk Inventor 2023. The machine design is shown in Figure 1.

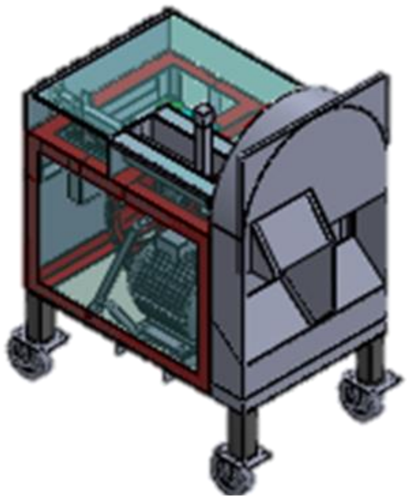

Figure 1. Design of the semi-automatic banana chips slicing machine

3.2 Machine working mechanism

The machine consists of four main working systems: banana input, transmission, slicing, and output. In the input system, bananas are placed in the material hopper and slowly pushed toward the blade using a pusher. Additional bananas can be inserted when the previous material approaches the slicing blade.

In the transmission system, the motor rotation is transmitted to the shaft so that the shaft rotates and drives the slicing blade die. The machine uses a single-phase electric motor with a nominal speed of 1400 rpm. The motor speed is transmitted through pulleys and a V-belt, producing a reduced shaft speed of 280 rpm, as shown in (3).

$$n_2 = n_1 \ x \left(\frac{D_1}{D_2}\right) = 1400 \ x \left(\frac{2}{10}\right) = 280 \ rpm \qquad (3)$$

The slicing system uses two stainless steel cutter blades driven by the slicing shaft. The slicing shaft speed is the same as the reduced shaft speed, namely 280 rpm, because the slicing shaft pulley is aligned with the reduction shaft pulley. In the output system, the sliced banana material exits through the opening in the protective blade cover.

3.3 Machine testing

Machine testing was conducted to determine the effectiveness of the semi-automatic banana chips slicing machine. The results of the blade-gap variation test are presented in Table 2.

Table 2. Results of blade-gap variation testing

No.	Trial	Blade gap (mm)	Standard shape (g)	Non-standard shape (g)	Slicing time
1	1	3	519	481	3 min 37 s
2	2	3.5	628	372	2 min 42 s
3	3	4	747	253	2 min 16 s

The 3 mm blade gap produced 519 g of slices meeting the standard shape and 481 g of non-standard slices, with a slicing time of 3 min 37 s. The 3.5 mm blade gap increased the standard slices to 628 g and reduced the non-standard slices to 372 g, with a slicing time of 2 min 42 s. The 4 mm blade gap produced the best result, with 747 g of standard slices, 253 g of non-standard slices, and a slicing time of 2 min 16 s.

3.4 Average slice thickness

The average slice thickness was measured using a vernier caliper. Tables 3-5 show the sample measurements for the 3 mm, 3.5 mm, and 4 mm blade gaps, respectively.

Table 3. Slice thickness at a 3 mm blade gap (mm)

No.	Thickness	No.	Thickness	No.	Thickness
1	2.20	11	1.85	21	2.00
2	2.00	12	1.85	22	1.75
3	1.60	13	1.90	23	2.35
4	2.25	14	2.20	24	1.70
5	1.75	15	2.25	25	1.60
6	1.80	16	2.00	26	1.85
7	2.40	17	2.00	27	1.85
8	2.10	18	2.10	28	2.00
9	1.75	19	1.75	29	2.20
10	2.00	20	1.50	30	1.65

Based on Table 3, the total measured thickness was 59.85 mm. Therefore, the 3 mm blade gap produced an average slice thickness of approximately 2.00 mm.

Table 4. Slice thickness at a 3.5 mm blade gap (mm)

No.	Thickness	No.	Thickness	No.	Thickness
1	2.25	11	3.00	21	2.85
2	2.55	12	2.30	22	2.50
3	2.75	13	2.25	23	2.70
4	2.45	14	2.50	24	2.25
5	2.50	15	2.90	25	2.45
6	2.70	16	2.80	26	2.50
7	2.25	17	2.30	27	2.25
8	2.60	18	2.35	28	2.75
9	2.50	19	2.50	29	2.25
10	3.00	20	2.25	30	2.35

Based on Table 4, the total measured thickness was 75.55 mm. Therefore, the 3.5 mm blade gap produced an average slice thickness of approximately 2.50 mm.

Table 5. Slice thickness at a 4 mm blade gap (mm)

No.	Thickness	No.	Thickness	No.	Thickness
1	3.05	11	3.05	21	3.25
2	2.75	12	2.75	22	3.20
3	3.55	13	2.90	23	3.25
4	3.05	14	2.85	24	2.70
5	2.85	15	3.00	25	2.80
6	3.50	16	3.25	26	3.00
7	2.75	17	3.50	27	3.00
8	3.00	18	3.00	28	2.55
9	2.70	19	3.50	29	3.05
10	3.35	20	3.25	30	3.25

Based on Table 5, the total measured thickness was 91.45 mm. Therefore, the 4 mm blade gap produced an average slice thickness of approximately 3.00 mm.

3.5 Machine capacity

Machine working capacity was obtained by slicing 1 kg of bananas and recording the required time. Based on the experimental results, the 4 mm blade gap was more effective than the other variations and was also consistent with the production needs of KWT Madu Lestari. The capacity calculation is shown in (4).

$$Q = 1\,kg\ x\ \left(\frac{3600}{136\ s}\right) = 26.47\frac{kg}{h} \approx 27\frac{kg}{h} \quad (4)$$

Thus, the theoretical slicing capacity of the machine at the 4 mm blade gap was 27 kg/h. This result indicates that the semi-automatic machine can support more standardized slicing and improve the efficiency of banana chips production compared with manual slicing

4 Conclusion

The semi-automatic banana chips slicing machine is feasible for use and meets the product requirements of KWT Madu Lestari. The driving power, expected appearance standard, and product advantages are aligned with user needs. The machine uses a 1/4 hp electric motor with a nominal speed of 1400 rpm and a reduction or blade shaft speed of 280 rpm. The most effective test result was obtained at the 4 mm blade gap, which produced an average slice thickness of 3 mm, 747 g of slices meeting the standard shape from a 1 kg sample, and a theoretical slicing capacity of 27 kg/h. Further research can evaluate longer operating durations, different banana maturity levels, and ergonomic improvements to the input system.

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Conflicts of Interest

The authors declare no conflict of interest.

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