Multidisciplinary Applied Research and Innovation Vol. 4 No. 2 (2023) 227-235
© Universiti Tun Hussein Onn Malaysia Publisher's Office

MARI

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/mari
e-ISSN :2773-4773

Efficiency of Semi-Automatic Banana Horn Cutting Machine

Mahmod Abd Hakim Mohamad[1*], Nurfarahin Onn[2], Muhammad Iqbal Zahin Arsam[2], Hossin Md Dzaid[2], Muhammad Affif Iskandar Rafie[2]

[1]Sustainable Product Development (S-ProuD), Department of Mechanical Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA.

[2]Department of Mechanical Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA.

*Corresponding Author Designation

DOI: https://doi.org/10.30880/mari.2023.04.02.031
Received 01 October 2022; Accepted 30 November 2022;Available online 15 January 2023

Abstract: A slicer is a device that can slice fruit, usually for the manufacturing of fried chips. The manual method of slicing a banana requires a lot of time and energy, and small and medium-sized businesses (SMEs) in Malaysia no longer use it. Low operating costs are the primary goal of SMEs, so this sector demands for low-cost, practical, and effective banana-slicing equipment. However, a small firm cannot afford to purchase fully automatic equipment because it is more expensive to maintain and requires skilled operators. This project aims is to offer an alternate method for SMEs to produce banana chips by developing and testing a semi-automatic slicer. The objectives are to create a semi-automatic slicer, test its functionality using a parametric approach, and assess how well it works. The machine can slice bananas and has a semi-automatic function. It is also user-friendly. To create a completely functional machine, the machine development process entails machine design using SolidWorks, material selection, metal works fabrication, which includes machining, cutting, and welding, assembly, testing, and remodification stages. The slicer was found capable of cutting the banana to the appropriate thickness during the machine test for slicing performance. Compared to the manual method, the time required to slice the fruits is 66 % faster, which is a major improvement while estimated at 55.71 Nm is the output torque determined from the design specification. The average slice thickness produces by the machine for bananas is 1.3 mm. This project has successfully achieved the objective of developing a semi-automatic slicer machine for small and medium-sized enterprises (SMEs). A parametric test to check the functionality and performance of the machine to slice a medium-sized banana has been performed, and the results have been evaluated.

*Corresponding author: hakim@uthm.edu.my

Keywords: Design for Functionality, Kerepek Pisang, Performed, Product Design

1. Introduction

Banana chips are one of the famous chips in Malaysia because many people will produce these chips for every Eid celebration each year. Production at that time was quite lucrative due to high demand from customers. Not only that, many produce their own banana chips at home instead of buying from the market. There are two types of banana chips, round shape and longitudinal shape as shown in **Figure 1**. Banana chips are made from various types of bananas such as "Pisang Nipah", "Banana Horn", and "Pisang Nangka". All these types of bananas have their own characteristics that will distinguish them. The supply of bananas usually comes from various sources. For industry, they need large quantities. Therefore, they will get supplies from any source like personal people who offer the best price. Sometimes they also plant their own banana trees in order to save costs for raw bananas. For the production of their own chips, people usually get supplies from markets or fruit stalls and even from their own gardens. In the production of banana chips, raw bananas need to be sliced round or longitudinally before being fried. Along with the development of technology, several countries have developed various technologies for slicing bananas, from just using a knife to the advent of more modern machines [1]. Currently, machines are the best way to cut bananas faster and are suitable for mass production.

(a) (b)

Figure 1: Types of banana chips: (a) round shape (b) longitudinal shape

2. Existing Product

Improving existing products or services in the market is an important factor in the implementation of a product and able to improve the quality of products or services. For example, many companies sell banana chip machines in the market that are used to increase productivity and sales, but is the machine suitable for all its uses to entrepreneurs. In addition, improving an existing product or service is also a process or system of making changes to a product or service that creates new customers or produces greater benefits enjoyed by existing customers.

2.1 Banana Cutting Machine (PSG-100)

The PSG-100 type banana cutting machine as shown in **Figure 2** has a frame made of stainless steel which has good advantages such as the machine will not rust, food will not be contaminated and so on. However, stainless steel makes this product expensive [2]. In addition, this machine is capable of cutting bananas quickly and in large quantities of 100 kg to 200 kg in one hour depending on the number of employees. It also has an electrical power of 200 watts, enabling this product to operate for a specific time. This machine does not take up too much space because it measures 63 cm × 66 cm × 84 cm and can cut round or longitudinal shapes.

Figure 2: Banana-cutting machine (PSG-100)

Table 1: Specification of banana-cutting machine PSG-100

Types	**PSG-100**
Quantity can produce	100-200 kg/hour (based on the worker)
Dimension	63 cm × 66 cm × 84 cm
Power	200 watt
Material	Stainless Steel
Result of cutting banana	Round and elongated

Table 1 show lists the specifications of the PSG-100 type banana-cutting machine.

2.2 Semi-Automatic Chip Processing Machine (AGV-01)

The design concept of a semi-automatic chip processing machine as shown in **Figure 3** has been produced based on an innovation research study by a group of Kuala Langat Community College students [3]. This machine combines all the main processes of producing banana chips such as slicing, frying and lifting in one place. Combining such processes saves production time and increases the quantity available. Next, this machine is made of stainless steel which has good advantages such as food will not be contaminated [4]. However, the use of expensive stainless steel materials causes the cost of this product to be expensive. Furthermore, this machine requires a relatively large space measuring 3' feet high × 2' feet wide × 5' feet long.

Figure 3: Semi-automatic chip processing machine (AGV-01)

Table 2: Specification of Semi-automatic Chip Processing Machine (AGV-01)

Types	AGV-01
Quantity produced	51 kg/day (6 hours)
Dimension	±3' ft tall × ±2' ft width × ±5' ft long
Power	250 watt
Material	Stainless Steel and Plated Steel
Result of slicing a banana	Round

Table 2 lists the specifications of the semi-automatic chip processing machine (AGV-01).

3. Materials and Methods

A component decomposition diagram was developed in this section, and the diagram's purpose is to get the initial vision of what the design will look like. It can also help the designer to figure out the component's assembly and the relation between all the components. **Figure 4** shows the project flow analysis.

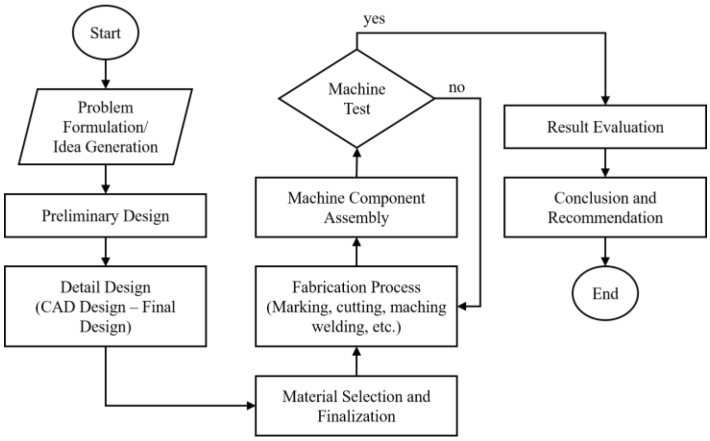

Figure 4: Project flow

The process of selecting the best sketch can lead to the main functions of the mechanism. The best sketches are selected according to several pre-determined criteria and specifications. The final sketch of the proposed *Kerepek Pisang* Machine was completed using SolidWorks 2018 software as illustrated in **Figure 5**.

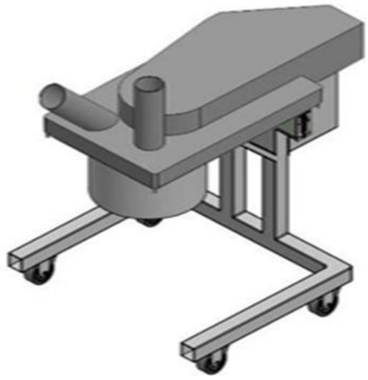

Figure 5: Sketch of the proposed concept

The following stage is a fabrication, which involves measuring and cutting raw materials into specific sizes and shapes, welding for permanent connecting, and completing a machine component before fully assembling all the parts to form a machine. The machine features are tested in the testing stage for their intended use. The method utilized by SMEs to assess the machine's performance is being compared to the machine's performance [5][6]. The machine will go through a re-modification procedure to accomplish the goals established whenever any portion or component of the machine deviates from or malfunctions in terms of functionality or performance. The testing outcome is documented and discussed for future work and other references.

3.1 Materials

Material selection is a crucial phase before proceeding with the fabrication phase. Good material selection can result in product quality, physicality and strength [7]. This main function is very important before producing a product. The main focus is to make a product that is a semi-automatic innovation of the banana chip machine manually. To achieve this objective, the strength and physicality of the material are significant to ensure that the product can stand stably and facilitate users to operate the machine.

Table 3: List of material and description

No.	Materials	Description
1.	Motor Power	The function of the motor is to move the blade to cut the banana. This motor used 240 volts of DC and the *Induction* motor is ½ hp
2.	Body (Stainless Steel Grade 304)	Stainless steel is used because it will not stain, corrode or rust as easily as mild steel. The size of the body is 790.5 mm in length, 650 mm in width, and 700 mm in height
3.	Blade / Cutting wheel	It is made of stainless steel. The blade size is 200 mm and 0.2 mm for thickness.
4.	Steel Plate	It covers and trims the outer frame structure. It is also lightweight and suitable for creating a machine that is easy to carry and practical [8].
5.	Belt	A belt transfers power between two shafts that are driven by pulleys. In this project, the circular belt type is used. The advantage of the timing belt is its compact design, and during operation, it does not require any lubrication [9].
6.	Bolts, Nuts and Washer	Bolts and nuts are used as temporary fasteners to install removable parts. A washer is used to prevent the fastener from being loose by the machine vibrations.

7.	Angle Iron	The angle iron will be used as a frame for this machine to support the body, and its material is stainless steel.
8.	Main Switch	This machine uses the Single Pole Single Throw (SPST) switch, which only has a single input and can connect to only one output.
9.	Aluminium Slinder Door Lock	It locks the machine door while running the machine to ensure the operator’s safety.
10.	Hinge	A door hinge is used to hold the machine access door during the maintenance or cleaning process.
11.	Mild Steel Shaft	The shaft transfers the rotation motion from the motor to rotate the cutting blade. The shaft diameter is 10 mm.
12.	Hollow Bar	Hollow bars support and be the main frame for the body of this machine. The physical characteristics of this component are light, strong and sturdy. Furthermore, it can withstand high pressure is applied to it.

Table 3 shows the list of materials and descriptions such as motor power, a body of stainless steel, a blade or cutting wheel, a steel plate, and the others component of the project.

3.2 Methods

Before the raw materials can move on to the joining step, they must first go through a measuring and cutting process. All metal parts are joined using the welding procedure when all the point where of the material needs to be permanently joined. There are two different kinds of welding techniques used. The first is stick welding, called arc welding, and gas tungsten arc welding, commonly known as tungsten inert gas (TIG). Stick welding is the most traditional, straightforward, and adaptable joining technique, and it works well to join thicker materials like the machine chassis. The Gas Tungsten Arc welding method is appropriate when welding stainless steel. MIG (metal inert gas) welding [10].

The procedure of assembling the frame comes next once the frame's fabrication and joining are finished, and the remaining components are prepared. Mechanical fasteners (e.g., nuts, screws, and bolts) connect most of the machine's parts. This fastener provides a number of benefits, including ease of assembly (usually requiring no special tools or equipment), high strength, and little part maintenance requirements. The cutting blade is rotated through a shaft by a 12 V DC motor. The motor has a 30 Nm torque. The typical force required to chop a banana is 22.4 N. Therefore, considering the highest force required, the minimum torque required to do the slicing can be calculated using **Eq. 1** [11].

$$T = Fr \qquad \textbf{Eq. 1}$$

Where T is the input torque, F is the slicing force, and r is the cutting blade radius. The radius for the cutting blade is 0.1 m, so the minimum torque required is 27.5 N.m. The torque from the motor is transferred to the cutting blade through a gear system. The gear attached to the motor has seven teeth, and the gear at the cutting blade shaft has 13 teeth. The speed ratio can be calculated using **Eq. 2** [12]. From the speed ratio, the output torque at the cutting blade shaft can be calculated using **Eq. 3** [13]. From the calculation, by neglecting all the frictional force, the output torque at the cutting blade is approximately 55.71 Nm.

$$\text{Gear ratio} = \frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}} = \frac{t_2}{t_1} \qquad \textbf{Eq. 2}$$

$$\text{Gear ratio} = \frac{\text{Output torque}}{\text{Input torque}} = \frac{T_2}{T_1} \qquad \textbf{Eq. 3}$$

The machine is tested during the testing phase to ensure that it operates and performs as intended. The machine slices bananas as part of the test. Each raw material that is fed into the machine is entirely sliced one at a time, and this time is recorded. The experiment is conducted three times for each raw material, and the average time is calculated. Under the machine functioning test, the machine's capabilities including cutting blade operation, electrical circuit operation, and simplicity of removal for cleaning and maintenance were examined. The medium-sized chopped banana was used in the performance test to evaluate the machine's durability and capacity. In this test, several raw materials are fed into the machine feeder at once.

4. Results and Discussion

The test results of the project were successfully obtained after performing the machine test at Arena Cipta (M) Sdn Bhd Sri Sulong using *Pisang Tanduk*. Therefore, the innovation of this machine can provide a higher amount of output than using the manual method at the same time producing the thickness of banana slices as expected.

Table 4 : Results testing for first time

No.	1	2	3	4	5	6	7	8	Average
Mass (g)	260	280	300	300	260	270	300	290	282.50
Time (s)	27.36	25.66	24.60	29.70	26.43	24.71	25.69	29.92	26.76
Thickness (mm)	1.40	1.60	1.30	1.40	1.30	1.30	1.20	1.20	1.36

Table 5 : Results testing for second time

No	1	2	3	4	5	6	7	8	Average
Mass (g)	300	300	300	250	300	300	300	300	300
Time (s)	19.50	19.20	20.18	22.18	20.10	22.13	23.14	17.52	20.49
Thickness (mm)	0.7	0.8	0.7	0.9	0.6	0.7	0.9	0.5	0.73

Table 6 : Results for manual slicing

No	1	2	3	4	5	6	7	8	Average
Mass (g)	300	320	250	270	300	290	270	300	287.50
Time (s)	109	143	87	92	125	114	95	110	109.38
Thickness (mm)	0.7	1.9	0.9	1.5	1.8	2.0	1.3	1.1	1.4

Table 4 shows the results of first-time testing for mass, time is taken and thickness of the banana chips. It shows that the average mass of a banana was 282.50 grams, and it took 26.76 seconds to complete slicing one banana with an average thickness of 1.36 mm. Meanwhile, **Table 5** presents the results of the second time testing with an average mass of 300 grams of banana, and 20.49 seconds to complete slicing one banana with an average thickness of 0.73 mm. Referring to this table, the weight of bananas successfully sliced using a semi-automatic banana-cutting machine is more than that using an oblique knife. **Table 6** shows the results of manual slicing which takes more time to complete slicing one banana (109.38 seconds) with an acceptable thickness (1.4 mm).

Figure 6 illustrates the time comparison for the banana-slicing process using a semi-automatic banana-cutting machine while **Figure 7** presents the time comparison for one banana-slicing process using a manual and a semi-automatic banana-slicing machine.

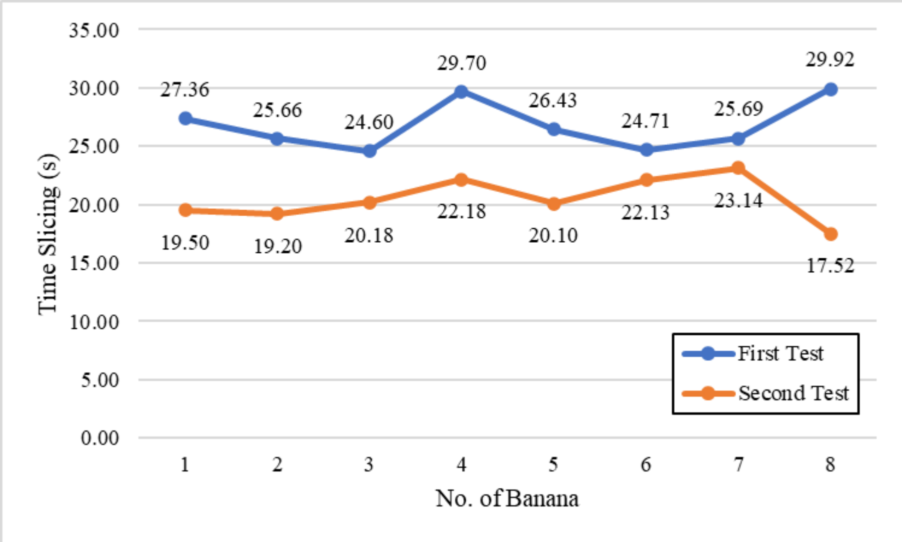

Figure 6: Time slicing for one banana using a machine

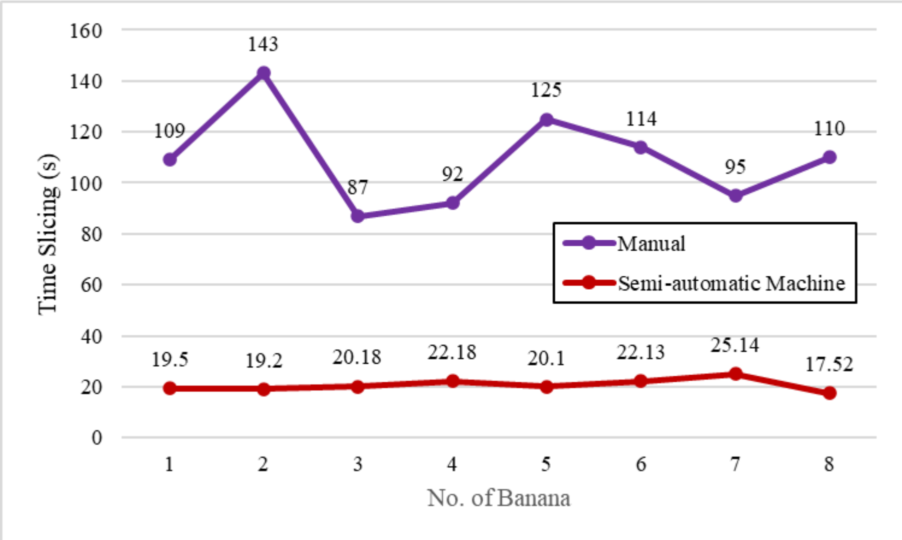

Figure 7: Time slicing for one banana between manual and machine

5. Conclusion

This project has successfully achieved the objective of developing a semi-automatic slicer machine for small and medium-sized enterprises (SMEs). A parametric test to check the functionality and performance of the machine to slice a medium-sized banana has been performed, and the results have been evaluated. The development of the machine involves design stages and metalwork fabrication. The total cost for this machine development is RM 4780.00. The machine is designed to be portable and user-friendly by implementing a mechanical fastener to assemble the machine's components such as the electric motor, power supply, and blade support for easy maintenance purposes. From the result, the machine can slice a medium-sized banana up to 66 % faster than the manual method using a multipurpose slicer. The average thickness of cutting banana was 0.8 mm. One of the operational efficiencies that are emphasized is the yield of banana chips. It should not be too thin or thick. The range required by banana chip operators is between 0.7 to 1.0 mm. The motor used is a single-speed non-variable motor with a production capacity of 1400 rpm and 240 V power. These parameters used help the banana slices to be of better quality. The advantages of this machine are user-friendly, easy to perform maintenance, is more efficient, less time to produce banana chips, and easy to handle. Nevertheless, this machine only focuses on slicing bananas and does not include the peeling process.

Therefore, for future recommendations, the automatic banana peeler mechanism must be added for better processes and improvement.

Acknowledgement

This research was funded by a product development grant (Vot B096) and has successfully registered intellectual property number LY2022J02309 provided by the Center for Innovation and Commercialization (ICC) Universiti Tun Hussein Onn Malaysia. The authors would also like to thank the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] M. H. Mokhtar, A. Ibrahim, H. A. Majid, and M. S. Muhamad, "Design and finite element analysis (FEA) of palm oil mill thresher drum spider arm," Journal of Design for Sustainable and Environment, vol. 1, no. 2, 2019

[2] C. Yan, L. Hao, A. Hussein, P. Young, and D. Raymont, "Advanced lightweight 316L stainless steel cellular lattice structures fabricated via selective laser melting," Materials & Design, vol. 55, pp. 533-541, 2014

[3] A. S. A. Kadir, M. Ismail, and K. Kasiran, "Crisps processor (AGV 01)," Politeknik & Kolej Komuniti Journal of Engineering and Technology, pp. 26-39, 2019

[4] J. D. Brooks, and S. H. Flint, "Biofilms in the food industry: problems and potential solutions," International Journal of Food Science & Technology, vol. 43, no. 12, pp. 2163-2176, 2008

[5] R. H. Da Silva, P. C. Kaminski, and F. Armellini, "Improving new product development innovation effectiveness by using problem solving tools during the conceptual development phase: Integrating Design Thinking and TRIZ," Creativity and Innovation Management, vol. 29, no. 4, pp. 685-700, 2020

[6] M. Hudson, J. Lean, and P. A. Smart, "Improving control through effective performance measurement in SMEs," Production planning & control, vol. 12, no. 8, pp. 804-813, 2001

[7] G. P. Souza, R. Sánchez, and J. N. F. De Holanda, "Characteristics and physical-mechanical properties of fired kaolinitic materials," Cerâmica, vol. 48, pp. 102-107, 2002

[8] M. Kleiner, M. Geiger, and A. Klaus, "Manufacturing of lightweight components by metal forming," CIRP annals, vol. 52, no. 2, pp. 521-542, 2003

[9] R. Perneder, and I. Osborne, "Timing Belt Drive Technology," in Handbook Timing Belts, Berlin, Heidelberg: Springer, 2011, pp. 107-157

[10] A. E. Ikpe, O. Ikechukwu, and E. Ikpe, "Effects of arc voltage and welding current on the arc length of tungsten inert gas welding (TIG)," 2017

[11] P.A. Omale, A. Iorhemba, and S. Baba, "Determination of stress relaxation of three varieties of Benue state grown yam tubers," European Journal of Advances in Engineering and Technology. Vol. 8, no. 3, pp. 9-18. April 2021

[12] F. Roos, and C. Spiegelberg, "Relations between size and gear ratio in spur and planetary gear trains," Technical Report TRITA-MMK 2005:01. pp. 1-35, November 2004

[13] J. Kammet, "Supplemental notes on gear ratios, torque and speed," CORC 3303-Exploring Robotics. 2013