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Semi-automatic Slicer

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Abstract: A slicer is a machine that can slice fruit commonly for fried chip production. Slicing a banana, tapioca and yam using the manual method is energy and time consuming which is no longer a choice among small and medium enterprises (SME's) in Malaysia. Low operation cost is the main intention in SME's production process thus cheap, convenient, and efficient method in slicing the fruits is a demand among this industry. However, fully automatic machine available in the market is not affordable for small business starter, requires higher maintenance cost and skill operator. This project presents the development and testing of a semi-automatic slicer and aims to provide an alternative solution for the SME's in producing chips from banana, tapioca, and yam. The objectives are to design and fabricate a semi-automatic slicer and to perform a parametric test to the slicer functionality and evaluate its performance. The machine operates in semi-automatic function, is user-friendly, capable to slice bananas, tapioca, and yam. The machine development process involves machine design using SolidWorks, material selection, metal works fabrication includes machining, cutting, and welding, assembly, testing, and re-modification stage to achieve a fully operational machine. The machine test for slicing performance indicated that the slicer capable of slicing the banana, tapioca and yam accordingly. The time taken in slicing the fruits significantly improves compared to the manual method by 66% faster. The output torque calculated from the design parameter is estimated at 55.71 N.m. The average slice thickness produces by the machine for bananas, tapioca and yam is 2.0 mm, 1.5 mm and 1.5 mm respectively.

Keywords: Multipurpose Slicer, Semiauto, Small and Medium-sized Enterprise

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1. Introduction

Banana, Yam and Tapioca are the most common snack food that can be found in Malaysia. There are served by frying them in hot oil that is named chips. This type of snack food produces and sold by small and medium-sized enterprises (SME's) in Malaysia. Those food are best served hot so people can feel the juicy and the crispy of the chips [1]. In Malaysia nowadays, it is reported that more than 800,000 people have been unemployed due to the Covid 19 pandemic [2]. This data includes people working in the SME's industry where numbers of workers in working capacity have been reduced to maintain safety and healthy working environment and survival of the enterprise [3]. The method and machine currently used in the SME's industry are not capable to produce a higher production rate in slicing the banana, tapioca, and yam with the reduction of workers due to the Covid 19 pandemic [4]. Based on this situation, this industry requires a machine that is capable to operates at a higher production rate and not only of slicing the raw material but of peeling, mixing, fry and vacuuming the product [5]. Most of the production time spends in chips making process is in the preparation of raw materials such as peeling, slicing, and cleaning for daily production where it is still done manually [5].

Slicing is the process of cutting raw material to reduce size through a sharp-edged object such as a knife or set of knives or rotating blades etc [5- 8]. In chips productions, yam, banana, and tapioca must be sliced into a specified size to produce a good eating texture to the product. In SME's, this process necessitates the use of human labour to slice the products. As a result, this process consumes a lot of time and manpower to complete the task [7]. In most micro and small enterprises, this process is still done manually. When manpower is being exposed to the usage of a sharp object for slicing in a long hour could promote to the safety issue and quality [9, 10]. It also necessitates competent labour to shorten production time. Manual tapioca, yam, and banana slicers for making chips were available on the market in a variety of designs, ranging from the most basic to the most complex. Figure 1 shows the slicers available in the market. Figure 1(a) [11] shows a type of manual slicer that requires human effort to press the slicer on top of peeled banana, tapioca, or yam. The manual cutter in a more complex form that utilizes a lever concept is shown in Figure 1(b) [12]. This type of slicer reduces the human effort required and can be mounted onto the floor for stability. However, both types of slicers can be dangerous to new users and children. An automatic slicer machine is another alternative method that can be used to slice the banana, tapioca, or yam as shown in Figure 1(c) [13]. Despite the high production rate, the cost to acquire the machine is not affordable for SME's and the size of the machine itself is not portable, requires a skilled worker to operate and additional maintenance costs.

(a) (b) (c)

Figure 1: (a) Simple manual slicer device [11] (b) Manual food slicer with level handle [12] (c) Fully Automatic Multi Slicer [13]

Hoque et al. [14] in their research develop a manual potato slicer using the rotary motion concept. The slicer is operated by rotating the handle located at the top of the machine. The feeding of raw potato is done manually into the feeding cylinder. This machine is capable of producing up to 88.8 % slicing efficiency with a throughput 59.90 kg/h of potatoes. This machine requires human energy to rotate the cutting blades. Win et al. [15] developed and analysed a potato slicing machine that operates using a shaft and rectangular rotating cutting blades that rotates at 467 rpm. A 20 mm in diameter and 600 mm length shaft made of mild steel is selected after a static structural analysis is done. The machine is capable of cutting on average 3.72 kg potatoes per minute with an average efficiency of 83.4%. In designing an automated vegetable cutter and slicer, Ganyani et al. [16] have chosen to implement a rotating cutting disc and a conveyor with a speed adjustment to suit different types of vegetable cutting rates. The rotating cutting disc and ejector plate are made interchangeable and enclosed in a compartment for safety purposes. The cost to build the machine is up to USD 890.73. However, for SME's business in Malaysia, it requires a small size, portable and affordable at cost machine to do the slicing and cutting task.

The main objective of this project is to develop a semi-automatic multi slicer that is portable and capable of slicing banana, tapioca, and yam. This machine is targeted for the SME industry that produces a low to medium size production rate. It was also designed using a suitable material for production for it to be affordable and suitable for the SME’s player. In this project, the design of the machine has only required the operator to push the raw material into the machine feeder using a pusher. This method reduces energy consumption and ensures safety to the operator. The machine is used to cut raw yam, tapioca, or banana into thin slices for making fried chips. This machine is expected to increase the production rate and product quality. The rest of this paper is organized as follow: The next section is present on the materials used and method implemented in the development of the machine. In section 3, the machine test result and evaluation. The conclusion and recommendations for future works are in section 4.

2. Materials and Methods

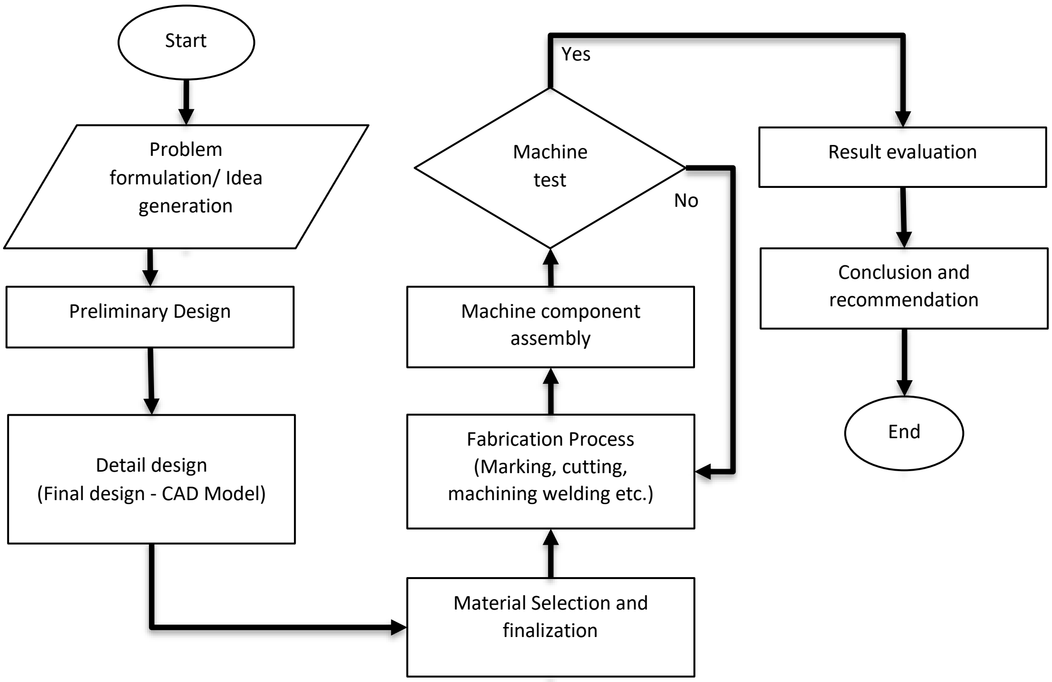
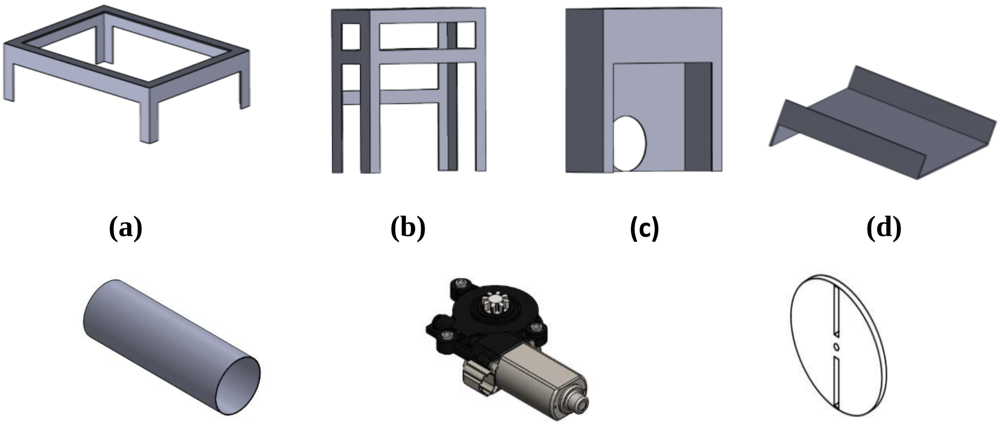


Figure 2: Project flowchart

In this project, the development of the machine has been divided into several stages. Starting with the problem statement and generating the idea for the project scope and objective. Next is the preliminary design of the machine according to the problem identified. At an early design stage, several sketches of machine design have been produced by manual sketches and the best design idea is being chosen for the next stage. The chosen design is then detailed in the detail design stage. At this stage, the dimension detail, component functionality and integration, material for each part and component of the machine is selected. Detailed CAD drawing of the machine part and component is then developed in Auto CAD 2019 and SolidWorks 2019 software. The component developed in the CAD software is shown in Figure 3 and an isometric view of the machine assembled in SolidWorks 2019 is shown in Figure 4.



(a) (b) (c) (d)

(e) (f) (g)

Figure 3: Machine main component (a) Base (b) Frame (c) Housing (d) Slide (e) Input Tunnel (f) 12V Dc Motor (g) Slicing blade

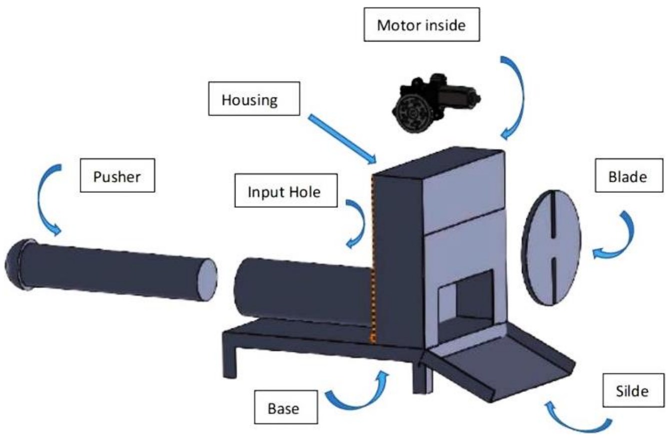


Figure 4: Design of the machine

The next stage is the fabrication stage that covers measuring and cutting of raw material into a designated size and shapes, welding for permanent joining and finishing process of the machine component before a complete assemble of all the components to be a machine. In the machine testing stage, the machine functionalities are tested to their designed purpose. The machine performance is being compared to the method used by SME's to evaluate its performance. Any deviation or malfunctioning of the part or machine component in terms of its functionality or performance, the machine will undergo a re-modification process to achieve the objectives set. The result of testing is being recorded and discussed for other references and future works. **Table 1** summarized the list of materials being used for this machine development and its descriptions.

2.2 Materials

Table 1: List of material and description

No.	Materials	Description
1.	Motor Power Window	The function of the motor is used to move the blade to cut the yam, banana and tapioca. This motor used 12 volts of DC and its weight was about 560 grams
2.	Power Supply 12V	A power source to the machine that converts 240 VAC to 12 VDC.
3.	Body (Stainless Steel Grade 304)	Stainless Steel Grade 304 is used because stainless steel is a type of steel that will not stain, corrode or rust as easily as mild steel. The size of the body is 450 - 500 mm for the length, 250 mm width and 300 mm for the height
4.	Blade / Cutting wheel	It is made of Stainless steel Grade 304. The blade size is 200 mm and 0.2 mm for the thickness.
5.	Electrical Wire	16 - Gauge wire used for the machine wiring to provide the maximum coverage of 10 amp of current from the power supply to the machine.
6.	Emergency Button	Function as a quick stop button to stop the machine in case of emergency.
7.	Bolts, Nuts and Washer	Bolt 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. This machine used M5 size for the bolt, nut and washer.
8.	Angle Iron	The angle iron will be used as a frame for this machine to support the body and the material is Stainless steel Grade 304.
9.	Main Switch	This machine used Single Pole Single Throw (SPST) switch which is it only has a single input and can connect to only one output.
10.	Aluminium Door Lock	Used to lock the machine door while running the machine to ensure safety to the operator.
11.	Hinge	A door hinge is used to hold the machine access door during the maintenance or cleaning process.
12.	Mild Steel Shaft	The shaft is used to transfer the rotation motion from the motor to rotate the cutting blade. The shaft diameter is 10 mm.
13.	Angle Protection Rubber	An angle protection rubber is used to protect user machine sharp edges during operation and maintenance.

2.3 Method

The raw materials selected go through a measuring and cutting process before they can proceed to the joining stage. In the stage, to join all the material permanently, the welding process is used as the method of joining for all metal parts. There are two types of welding methods that are applied. First is Gas Tungsten Arc Welding which is also called tungsten inert gas (TIG) and Stick Welding which is also known as arc welding. The stick welding method is the oldest, simplest and most versatile joining process and is suitable to join thicker material such as the machine chassis [17]. The Gas Tungsten Arc welding is suitable to do a welding process on a stainless steel material. Metal inert gas (MIG) welding can be used to weld carbon steels, low alloys steels, stainless steels, most aluminium alloys and zinc-based copper alloys [18].

Once the frame fabrication and joining process completed and the rest component is ready, the assembly process is next in line. Most of the components within the machine are joined by using mechanical fasteners such as nuts, screws and bolts. This fastener has an advantage such as ease of assembly which generally does not require special tool or equipment and have high strength as well as a low part maintenance requirement. A 12V DC motor is used to rotate the cutting blade through a shaft. The torque for the motor is 30 N.m. An average force to cut banana, tapioca and yam is 22.4N [19], 275N [20], and 79.3N [21] respectively. Therefore, taking into consideration the highest amount of force required, the minimum torque required to do the slicing can be calculated using Eq. 1 [22].

$$\mathrm{T} = \mathrm{F.r} \qquad \textbf{Eq. 1}$$

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 and therefore 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 7 teeth and the gear at the cutting blade shaft has 13 teeth. The speed ratio can be calculated using Eq. 2 [23]. From the speed ratio, the output torque at the cutting blade shaft can be calculated using Eq. 3 [24]. From the calculation by neglecting all the frictional force, the output torque at the cutting blade is approximately 55.71 N.m.

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

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

In the testing stage, the machine is tested to its design functionality and capability. In the slicing test, the machine is used to cut raw yam, tapioca and banana. The time taken for each fully cut of each raw material inserted into the machine is recorded. The experiment is repeated 3 times for each type of raw material and the average time is calculated. The machine functions such as cutting blade operation, electrical circuit operation and ease of removal for cleaning and maintenance were tested under the machine functionality test. The performance test has been conducted to test the capability and durability of the machine to slice a medium-sized cut banana, yam, and tapioca. In this test, the numbers of raw materials are inserted simultaneously into the machine feeder and evaluate the machine capabilities. The maximum numbers of raw material allowed to be inserted into the feeder are set to five numbers.

3. Results and Discussion

The machine is tested to obtain and analyse the results for its targeted objectives. The test that has been carried out and determined includes machine functionality test, machine performance and slicing rate. The result of testing is shown and discussed in the next section. The time taken by the machine is then compared to the time taken using a multi slicer to cut the raw materials.

3.1The slicing time of the machine.

The average time taken to slice each cut raw material is presented in **Table 2**. From the table, the result of this machine is compared to multi-purpose slicer slicing time. From the table, the time to slice a medium-sized raw banana, yam and tapioca is reduced by 65.6%, 66.5% and 66.6% respectively.

Table 2: Slicing time comparison

Item	Time taken to cut using multipurpose slicer (s)	Time taken to cut using semi-auto multi slicer (s)
Banana	27.09	9.23
Yam	52.15	17.48
Tapioca	86.23	28.77

The result of this machine shows that the semi-automatic multi slicer takes a shorter time to slice a medium-sized banana, yam and tapioca compared to the multipurpose slicer. The multipurpose slicer takes a long time because each slice consumes human energy and require a skilled worker but the semi-automatic multi slicer uses an electric motor to perform the slicing action.

3.2 Machine functionality test

In this machine design, the electrical circuit and cutting blade functionality are essential. In the test, the electrical circuit operation is safe to use and is connected to every component in the machine such as LED, 12V DC motor, switch, and emergency button. The cutting blade runs smoothly, and the gear is neatly attached to the blade. The motor and blade are capable to slice yam and tapioca although they have a hard texture compared to bananas. The raw slice exit through the slider to the machine collector. The slider and the blade can be removed easily from the machine for easy cleaning after being used to maintain the hygiene of the machine. **Table 3** shows the average thickness of raw material slice using the semi-automatic machine and multipurpose slicer.

Table 3: Slicing time comparison

Raw Material	Thickness (mm)	
	Multipurpose Slicer	Semi-automatic Slicer
Banana	2.0	2.0
Yam	1.4	1.5
Tapioca	1.4	1.5

The average thickness of a single slice produce by this machine for medium-sized cut banana, yam and tapioca is 2.0 mm, 1.5 mm, and 1.5 mm respectively. The slices produced by the machine is for banana is identical to the multipurpose slicer but for yam and tapioca, the thickness approximately 7% thicker. The thickness produced by the machine cutting blade is within the range of acceptable thickness for chips making process [25].

3.3 The performance of the machine

The results of the performance test conducted on the machine are in **Table 4**. From the Table, the machine is capable of slicing bananas up to five numbers simultaneously. Whereas for the yam in medium-sized cut, this machine is only capable to cut up to three inserted raw yams simultaneously but for the tapioca, this machine is only capable to cut up to two numbers of raw inserted.

Table 4: The capability of the machine

No. of Raw Material	Banana	Yam	Tapioca
1	Pass	Pass	Pass
2	Pass	Pass	Pass
3	Pass	Pass	Failed
4	Pass	Failed	Failed
5	Pass	Failed	Failed

The banana is softer in its texture compared to yam and tapioca which allow the blade to cut through it. However, from the observation, the cutting blade speed is reduced if the machine is switched for more than 2 minutes continuously. This is due to the motor being overheated. The increase in motor temperature has decreased the motor power results in low torque at the slicing blade and lowering the capabilities of the cutting blade to cut the raw yam and tapioca inserted [26].

4. Conclusion

This project has successfully developed a semi-automatic slicer machine that is targeted at small and medium-sized enterprises (SMEs). A parametric test to check the functionality and performance of the machine to slice a medium-sized banana, yam and tapioca has been performed and the results evaluated. The project objectives have been successfully achieved. The development of the machine involves design stages and metalwork fabrication. The total cost for this machine development is RM 448.00. The machine is designed to be portable and user friendly by implementing a mechanical fastener to assemble machine components such as electric motor, power supply and blade support for easy maintenance purposes. From the result, the machine is capable of slicing a medium-size banana, yam and tapioca up to 66% faster than the manual method using a multipurpose slicer. The average thickness produces by the machine in cutting banana, tapioca and yam are 2.0 mm, 1.5 mm, and 1.5 mm respectively. On top of that, this machine operates at semi-automatic functions which promote less energy usage compared to the manual method. For improvement, the motor can be replaced with a higher torque motor to slice bigger size raw material.

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