UNIVERSITI PUTRA MALAYSIA

DESIGN AND FABRICATION OF BANANA SLICER FOR SMALL SCALE INDUSTRIES

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ABSTRACT

Banana is a tropical fruit that can be cooked by boiling, steaming, baking, roasting or frying and processed into banana chips. Banana chips made from unripe banana which have high demand in market especially during Malaysia festive season. It comes with variety of flavor and shapes, where the most found shapes are circular and longitudinal.

However, the production of longitudinal banana chips is slow due to its drudgery and crude method. Besides, the existing invented machine did not meet the entrepreneur's expectation as they were concerned to produce banana chips with uniform thickness. Therefore banana slicer machine is designed and develop to replace the manually method.

A semi-automatic banana chips machine have been designed and fabricated with dimension of 0.97 m (length) x 0.5 m (width) x 1.24 m (height) The present invention is made up of the feeding mechanism, cutting mechanism, a deep-fryer, an induction motor electric as power supply, a shaft, a working cabinet with load system and a skeleton which connected working cabinet to the cutting mechanism. The machine is able to slice banana in circular and longitudinal shape. The operation of this machine begins with the input of banana to the circular or longitudinal feeder at one time, to be slice by the rotating cutting disc. The banana is move horizontally toward the cutting disc due to the gravitational force of pusher that connected with load system at the working cabinet. The cutting disc is able to rotate in counter clockwise via a shaft connected to the induction electric motor and slice the banana completely. The sliced banana will

discharge out from the chute of cutting chamber to the deep-fryer to produce fried banana chips.

The performance of the machine is tested using the circular and longitudinal feeders of the banana slicer machine. As results, the production rate of longitudinal sliced banana takes 12.2 kg/hr which is better than manual method that takes 1.62 kg/hr. The banana slicer machine also able to slice other multi-food solid such as cassava, sweet-potato and carrot and their production capacity are 12.96 kg/hr, 16.56 kg/hr and 31.68 kg/hr respectively.

ABSTRAK

Pisang adalah buah-buahan tropika yang boleh dimasak dengan cara merebus, mengukus, membakar, memanggang atau menggoreng dan boleh diproses menjadi kerepek pisang. Kerepek pisang–yang diperbuat daripada pisang muda (belum masak) mempunyai permintaan tinggi di pasaran terutama pada musim perayaan. Ia datang dengan pelbagai rasa dan bentuk, dimana bentuk yang paling digemari adalah bulat dan memanjang.

Walau bagaimanapun, pengeluaran kerepek pisang bentuk memanjang adalah lebih rendah kerana proses pembuatan masih secara manual/tradisional yang melecehkan. Selain itu, mesin sedia ada tidak memenuhi kehendak usahawan dimana mereka mengkehendaki kerepek pisang pada ketebalan yang seragam. Oleh itu, mesin penghiris pisang direka dan dibangunkan untuk menggantikan kaedah manual.

Sebuah mesin pembuat kerepek pisang semi-automatik telah direka dan dibangunkan dengan saiz mesin diantara 0.97 m (panjang) x 0.5 m (lebar) x 1.24 m (tinggi). Inovasi mesin ini terdiri daripada mekanisme suapan, mekanisme menghiris, periuk menggoreng, motor sebagai bekalan kuasa, aci, kabinet simpanan dengan sistem beban dan kerangka yang menghubungkan cabinet simpanan dengan mekanisme pemotongan. Mesin ini mampu menghiris pisang dalam bentuk bulat dan bujur. Operasi mesin ini bermula dengan memasukkan pisang ke dalam corong bulat atau bujur, dan cakera pemotong berputar akan menghiris pisang ini. Sampel pisang akan bergerak secara mendatar ke hadapan menuju ke arah cakera pemotongan berputar disebabkan oleh gerakan daya graviti pada sistem beban di cabinet simpanan yang bertindak sebagai

penolak. Cakera pemotongan berputar bergerak dalam arah lawan jam melalui aci yang disambungkan ke motor aruhan elektrik dan pisang akan terus dihiris sehingga selesai. Hirisan pisang yang keluar dari corong kelua akan terus masuk ke dalam periuk menggoreng untuk bagi menghasilkan kerepek pisang.

Prestasi mesin diuji dengan menggunakan corong bulat dan bujur. Sebagai keputusan, kadar pengeluaran pisang bentuk bujur menghasilkan 12.2 kg/jam yang lebih baik daripada kaedah manual yang mengambil 1.62 kg/jam. Mesin kerepek pisang ini juga mampu untuk menghiris atau memotong pelbagai jenis produk makanan seperti ubi kayu, ubi keledek dan lobak merah. Kadar pengeluaran bagi setiap produk makanan tersebut adalah 12.96 kg/hr, 16.56 kg/hr and 31.68 kg/hr.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to banana slicer

A banana slicer is a machine where banana is force to penetrate through a knife or blade where a tuber banana is changed in shape into slices of banana. Usually, this slicer is adapted to produce banana chips.

Banana slicer has been used widely by entrepreneurs of Small and Medium Enterprise (SME) in producing banana chips. It helps to save time and energy of the labors and fast production. Previously, the banana is sliced using a sharp knife placed at the wooden board by hand. This method has been widely applied in small scale industries in Malaysia especially in producing longitudinal banana chips; somehow this traditional method gives some problems which are fatigue, slow production and energy consuming. Other than that, this method will cause injuries to the workers as they move the food products penetrate through the sharp blade which usually placed on the cutting board, and lead to the production of poor uniformity thickness of sliced banana when they consume lots of energy.

After that, the invention of banana slicer is enhanced by introducing slicing machine which is very necessary to reduce the hard work of continuous cutting of bulk banana with a knife. However, this commercialized slicing machine gives rise to several inherent problems. One of the most concerned problem is it was difficult to find slicer that can produce banana chips in longitudinal shape since the demand of banana chips in longitudinal shape is high in market (Faizul, 2016). Furthermore, the existed of that particular slicing machine available in market usually imported and expensive. For instance, the commercialized slicing machine comprised of three hoppers with lids, cutting mechanism and electric motor as power supply. The cylindrical hopper acts as feeder that is vertically subjected to the cutting disk which attached with two blades. Banana will be loaded into the hoppers to be slice by the cutting disc to produce sliced banana in circular shape and lids act as pusher to push banana. The machine operated by the power transmitted by the motor through the pulley system that will spin the cutting disc. However, this machine also had problem which in case the banana flesh or residues get caught in the hoppers, it is hard to take them out and might cause finger injuries due to the exposure of the blades.

The other commercialized slicing machine comprised of conveyer as feeder that loaded banana to cutting wheel to be slice in vertical direction. The cutting wheel is designed to be able amounted to amount with appropriate number of blades to the cutting wheel (Bucks & Valparaiso, 2000). However, thickness of the sliced banana might not be uniform due to the timing of cutting wheel with the forward motion of the feed conveyer. Therefore, commercialized slicing machines need improvement to overcome the problems inherent in the process of preparation of banana slicer.

1.2 Market prospect of banana chips industry in Malaysia

Banana chips became staple food for millions people in the world. Every people can consume banana chips regardless age and race. In Malaysia, there is high demand on banana chips especially during festive seasons. Customers were willing to queue in order to get the banana chips to they served for their guests. During ordinary day, banana chips are consumed by people during tea time and usually banana chips are brought by office workers, school children and travellers as snack. According to Ababa (2000), by indicating banana as the main ingredient, it is a good source of potassium that help to keep body fluids in balance. Other than that, it also an ideal food for toddlers, sick people and people living with HIV/AIDS

Based on the results of survey performed in 2003 that involving entrepreneurs in processing of banana chips, the demand for domestic and export are shown in Figure 1.1. The Figure 1.1 shows that 17% of entrepreneurs taught that their domestic market as very good, 59% as good, 20% as unsure,2% as not satisfactory and 2% as not good.

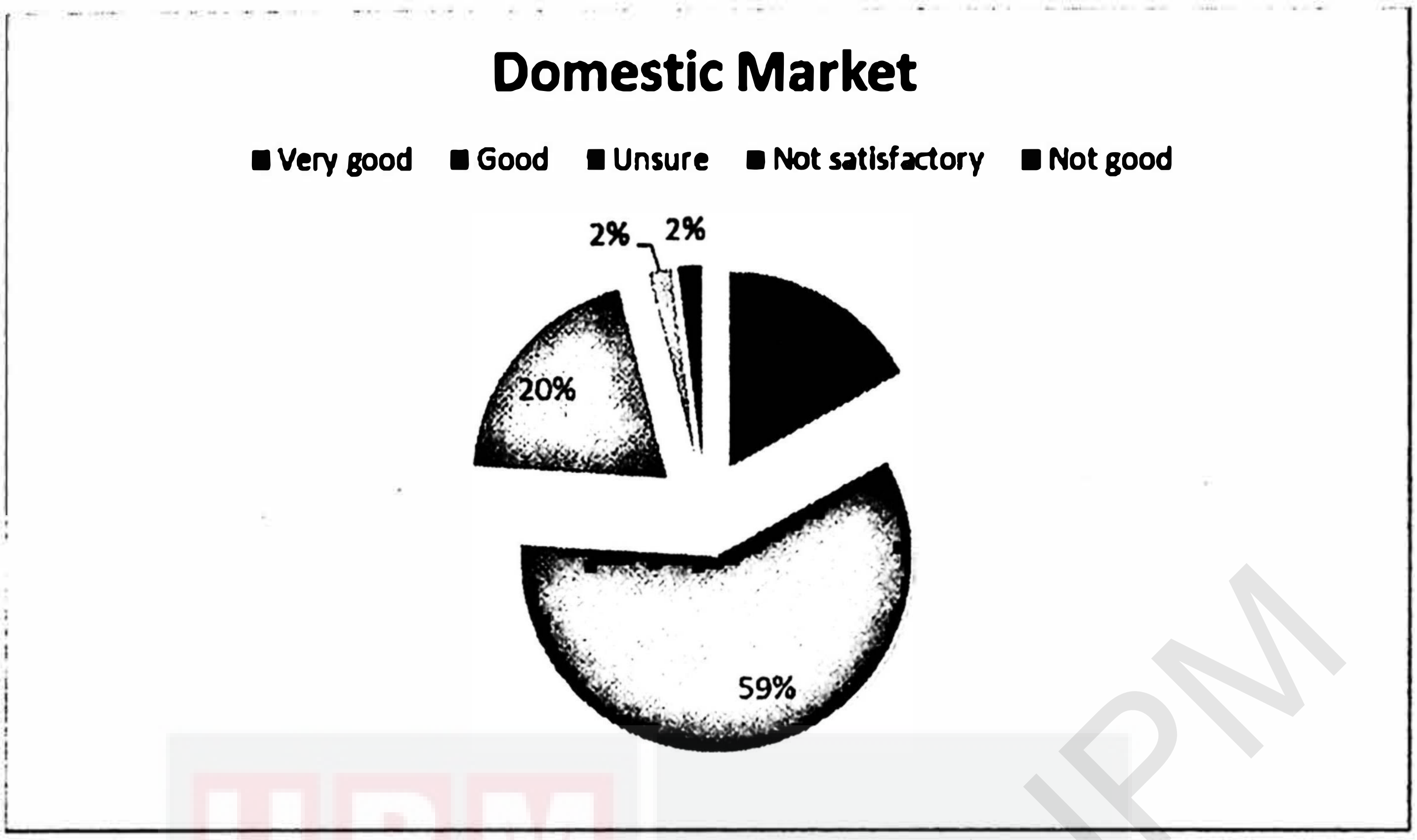


Figure 1.1 Demand of banana chips industry for domestic market(Auni, H& M. Khairol ,M. Ariff, 2006)

For export market, there are only eight entrepreneurs are involved in exporting their products which mainly exported to Singapore. Twenty-seven percent of them cited their export market as very good but there is 27% of them cited as not good. However, 36% indicated their export market as good and 9% are still unsure. From that, we can conclude that the exporting banana chips in market still at appearing stage but have high potential.

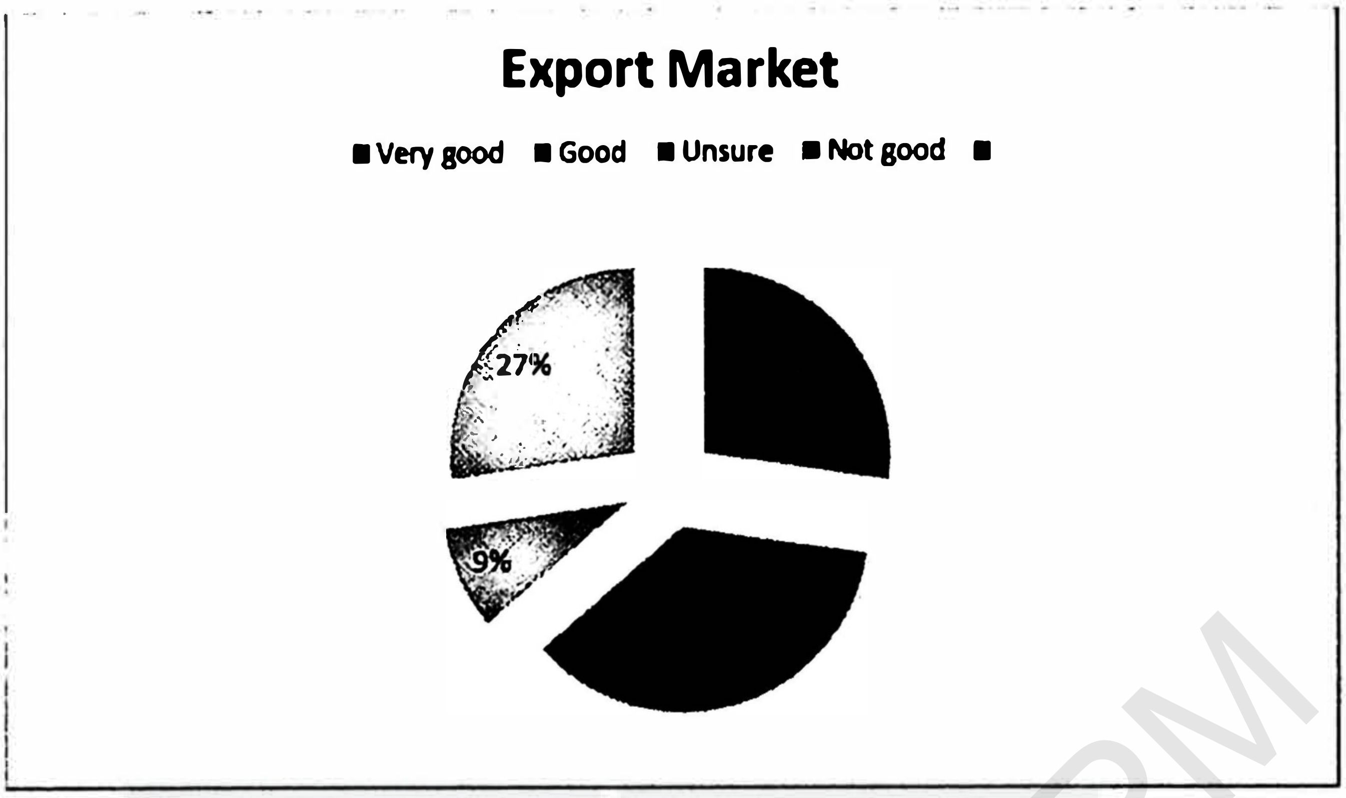


Figure 1.2 Demand of banana chips industry for export market (Auni, H & M. Khairol, M. Ariff, 2006)

Besides that, 70 % of responses specified that their market for banana chips increasing based on their last 5 years' experience which is the sale trend increasing at an average rate of 33%, ranging from 3–100%. Meanwhile, 77% indicated that their market would expand in the future by 36% for the next 5 years. Generally, both the domestic and export markets are considered as good. Based on the results of the study, the banana chip industry is a developing industry.

The increasing consumption of the banana chips is expected in future due to the growing consumer concern towards ethnic food and healthy food. Other than that, other factor that may contribute to the increasing demand of the banana chips is there is an increasing number of working women who spent less time cooking. According to Department of Statistic Malaysia (2016), the percentage of Female LFPR rose 0.2 points to 54.3% in 2016 compared to 2015.

1.3 Problem Statement

The target of the small scale enterprise (SME) in preparing banana chips is to produce high yield production with uniform thickness and preserve the quality of the banana chips. In custom, banana chips which made from unripe banana have high demand in market especially during festive season. It comes with variety flavor and shapes, and the most found shapes are circular and longitudinal.

Slicing machine had been invented in making banana chips to meet the requirement needed. Most of the problems mentioned above had been nearly solved by the existing machine but only for producing banana chips in circular shape. In fact, the production of banana chips in longitudinal shape was still use traditional method where the banana is sliced using wooden board comprises of blades on it. The banana is force to penetrate the blades to get the sliced banana. This method cause slow production which takes about 40-80 seconds for a tuber of banana to be sliced which at average of 60 seconds, the capacity is 1.62 kg/hr. For a day and a month, a skilled worker can produce capacity about 38.88 kg/day and 1166.4 kg/. Othe than that, this method is energy consumed and the risk of injuries is high due to the exposure of the blades. Besides that, uniform thickness is hardly achieved and human error during slicing is high due to the energy consumed.

Banana chips in longitudinal shape has higher demand than the circular shape (Faizul, 2016). This is because long banana chips give more delectation of munching. People tends to keep munching once they start eating the banana chips and long banana chips gives more enjoyment of munching due to its long size. Therefore, new design of banana slicer should be made to solve the problem faced by the entrepreneur to replace the drudgery and crude method

1.4 Objectives

The objectives of the project are:

i. To design and develop banana slicer machine that can slice banana in longitudinal shape
ii. To determine the performance of the machine at different food products such as cassava, sweet potato and carrot

1.5 Scope of the Study

The scope of study of this project should be included:

i. The invention of this machine usages for small scale industries
ii. The machine is design for batch processing
iii. The machine could be used for cutting other food products such as cassava, sweet potatoes and carrots

CHAPTER 2

LITERATURE REVIEW

2.1 Banana

Banana (*Musa Paradisiaca L.*) is known as fourth largest fruit crop in the entire world. It comes from species of "Musaceae" and genus of "Musa", where the tree of this tropical fruit can grow best in rich, moisture and well-drained soils with 45% clay, 70% silt and 80% loam ("Banana Farming Information Guide," 2017). The suitable temperature for the growth of the tree is between 24°C to 27°C with rainfall around 10 cm per month and the trees that can height until 8 meters ("Fruits in Malaysia," 2010). The bananas have concentrated area of planting located in Johor, Pahang, Selangor, Perak and Sabah (Anem, 2012).

Apparently, several bananas are attached in a single bunch where the individual banana fruit has a protective outer layer (skin) with a freshly edible inner part (flesh) (Obayopo et al, 2016). The skin of banana turns from deep green to yellow colour when it was going to ripe. Greenish colour shows that the banana is young with starchy taste while yellowish colour shows that the banana is mature. Besides, the colour of flesh also varied from white to yellow. The white colour of flesh indicates that the banana is unripe while the ripe banana, the colour of flesh is in yellow colour. The taste of banana flesh varied from starchy to sweet depends on the varieties and ripeness. Yellow banana taste sweeter compared to white banana due to higher sugar concentrations. Usually, unripe banana is firm and gummy with latex then turns soft and dry when ripe. This fruit can be found at all period in Malaysia ("Fruits in Malaysia," 2010).

The ripe banana can be consumed by raw and cooked. It can be cooked by boiling, steaming, baking, roasting or frying (Obayopo et al., 2016). On the other hand, the unripe and green banana is suitable used for making banana chips. In the process of making banana chips, the bananas that have been peeled into thin slices are deep-fried in an edible oil such as palm oil or coconut oil until golden brown. After that, banana slices are removed from the hot oil and served (Regina, 2003). The banana chips can be served with sugar or honey for sweet taste, or they can be served with salt and spices for salty and spicy taste (Aida et al, 2016).

2.1.1 Varieties of banana in Malaysia

Banana is listed as one of the 15 fruit types prioritized for commercial cultivation in the Third National Agricultural Policy. This indicated that banana is an important fruit crop for Malaysia both for domestic and export market (1998-2010) (Hassan, 2002).

There are many local varieties of banana grown in Malaysia such as Pisang Berangan, Pisang Awak, Pisang Susu, Pisang Tanduk, Pisang Lang, Pisang Nangka, Pisang Mas, Pisang Abu, Pisang Nipah, Pisang Rastali, Pisang Masak Hijau and many others (Anem, 2012). Despite that, Cavendish banana, Pisang Berangan, Pisang Mas, Pisang Rastali, Pisang Tandok, Pisang Nangka, Pisang Raja, Pisang Awak and Pisang

Abu or Nipah are the major or potential commercial cultivars in Malaysia (Hassan, 2002). Banana varieties such as berangan, mas, rastali and Cavendish are used in cookery while nipah, nangka, tanduk and pisang awak are used in desserts (Lim Chia Ying, 2015).

Table 2.1 The varieties of banana in Malaysia and its charactheristics ("Banana Farming Information Guide," 2017)

Varieties of banana	Charactheristics
Berangan	Cluster weight between 12 to 20 kg with 8 to 12 comb bananas. Each comb may contained 12 to 20 bananas with 12 to 18cm long banana fruit and skin thickness 2.5 to 3.5 mm. Oren yellowish flesh fragrant with sweet taste and dry. Normally eaten raw.
Mas	Cluster weight between 8 to 12 kg with 5 to 9 comb bananas. Each comb consist of 14 to 18 bananas with 8 to 12 cm long banana fruit. Golden yellowish flesh is sweeter. Normally eaten raw.
Cavendish	Cluster weight usually above 20 kg with 15 to 25 comb bananas. The bananas long 15 to 22 cm banana fruit. White flesh ,soften and sweet fruit.
Rastali	Cluster weight between 10 to 15kg with 5 to 9 comb bananas. Each comb consist of 12 to 16 bananas with 10 to 15 cm long banana fruit. White flesh ,soft with sweet sour flavor. Normally eaten raw.
Tanduk	Cluster weight between 7 to 10kg with 2 comb bananas. Each comb consist of 7 to 10 bananas. Orange flesh and sweet taste. Normally use to fried and eat raw.
Raja	Cluster weight between 10 to 15 kg with 6 to 9 comb bananas. Each comb consist of 12 to 16 bananas with 15cm long banana fruit. Orange flesh . Normally eaten raw or fried banana.
Nipah	Cluster weight 15 to 28 kg with 12 to 18 comb bananas. Each comb consist of 12 to 20 bananas with 10 to 15 cm long banana fruit. White flesh ,sweet

	and soft. Only eaten after fried.
Nangka	Cluster weight between 12 to 14 kg with 6 to 8 comb bananas. Each comb consist of 14 to 24 bananas. White flesh and lithe sour flavor. Normally eaten fried banana.

2.2 Slicing due to the shear force

Slicing operation is where minimum rupture and deformation of materials are achieved by moving, pushing or forcing thin sharp blade or knife through the materials (Raji et al., 1994). Meanwhile, shearing force is the amount of force required to cut or remove a piece of material through shear, as is done in cutting, blanking or punching operations (CustomPartNet, 2014).

Slicing processes also may referred as shearing force. This is because most slicing processes conducted utilize shearing force. In order to cut a material, a great enough shearing force must be created to allow the shear stress in the food material exceed the ultimate shear strength which caused it to fail and separate at the cut location. However, the term of shearing refers to a specific cutting process that produces straight line cuts, but angled cuts also can be made. Therefore, shearing is mainly used to cut food material into smaller size in preparation for further processes.

Usually, food materials are sliced for preparation before cooking, steaming, boiling or other relevant operations, either for direct consumption or as one step in a processing system. Slicing caused reduction in size of the food materials that brought by mechanical tools without change in chemical properties of the material and uniformity in size and shape of individual units of the end product (Agbetoye, 2015).

The process of slicing of the food materials works as catalyst in drying and frying process. It is an important operation to achieve size range. As the size of the raw food is reduce, more surface area is exposed for drying which this facilitate the rate of heat transfer and removal of moisture from the pieces. The sliced of raw food takes less time to cook than the unsliced food due to its smaller size (UNIFEM, 1989). The quality of the food product could be ensure with proper frying where this process help in reducing moisture content thus extending its shelf life. George O. Abong et al,. (2011) reported that a properly packaged fried crisp product can be stored up to six months.

Size reduction of the raw food material also can be achieved by cutting, shredding, crushing, chopping, grinding, milling and grating. For example, cutting of fruits and vegetables for dishes and dessert, shredding sweet potatoes for drying, chopping meats for easily cooked and chewed, grating cheese for pastries and western food and grinding grain for livestock feed and milling.

2.3 Procedure of making banana chips manually

The understanding on process of making banana chips manually is an important before designing and fabricating a suitable and practical machinery of banana slicer. There are three basic steps making banana chips manually which are peeling, slicing and frying.

In this process, the ingredients need only unripe or green banana, salt and oil. The first step starts with peeling the banana to remove its skin by cut both pointed ends and lifting the skin of with knife. After that, the bananas need to be soaked in basin of water to wash off latex and browning prevention.

The next process is slicing which known as toughest step. The bananas need to be slice in uniform thickness by cutting board that made from wood or plastic. In order to get the best crispness of fried banana chips, the appropriate thickness for making banana chips is must be obtained which is ranging between 1.0 mm to 1.2 mm (Faizul, 2016). The sliced bananas are then put in the fryer contained of edible oil for frying with temperature of 180 °C for 4 minutes until they obtained yellowish color.

2.4 Patent

Patents are form of intellectual properties which are set of exclusive right granted by a sovereign state to an inventor or their assignee for a limited period of time, in exchange for public disclosure of the invention. A patent protects new inventions and cover how things work, how they do it, what they are made and what they are made from. If the patent is granted to the owner of invention, it gives the owner the ability to take a legal action under civil law to stop others from making, using, importing or selling the inventions without permission.

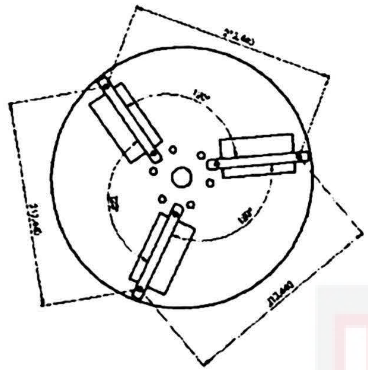
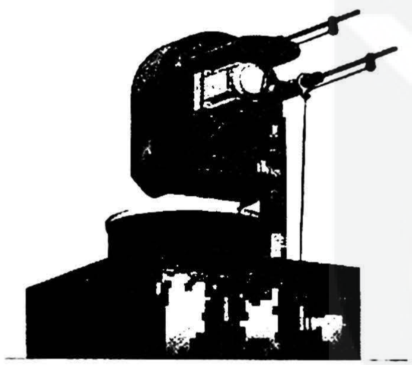
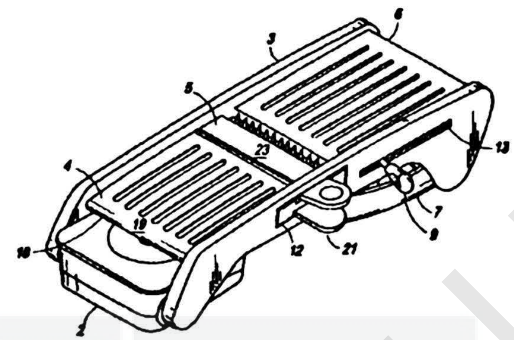
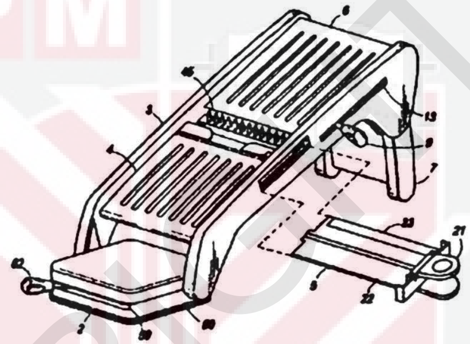
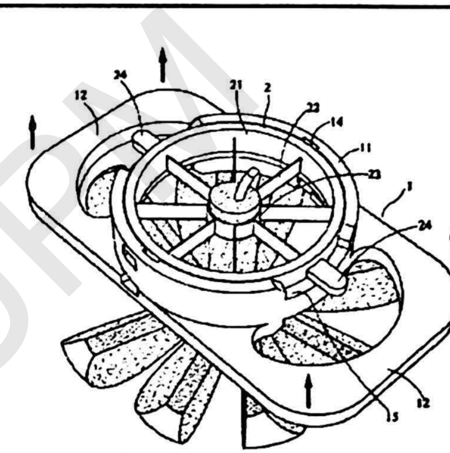
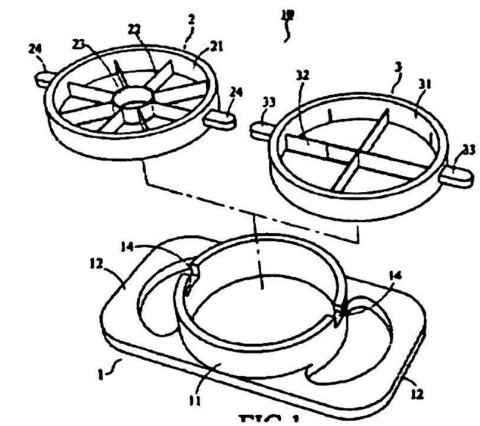
2.4.1 Prior Art

Prior art is all the information that has been disclosure to the public in any form about an invention before a given date.

In this project, prior arts were done on patent related to invention of banana slicer, food slicer and potato slicer.

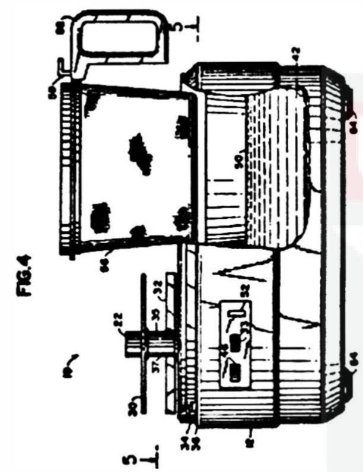
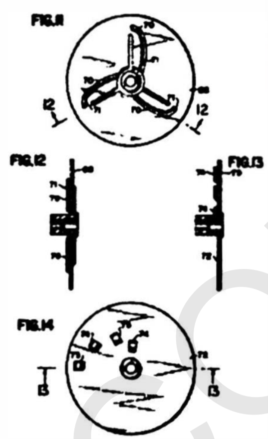
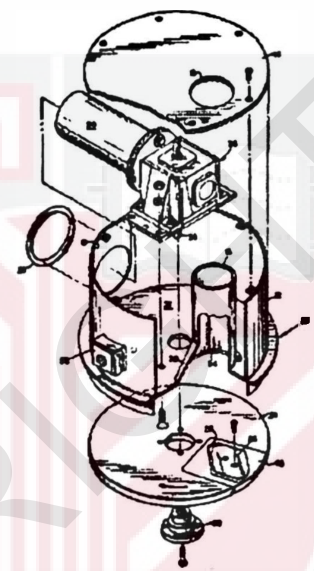
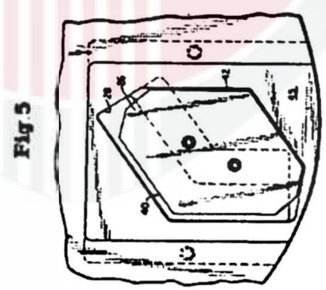
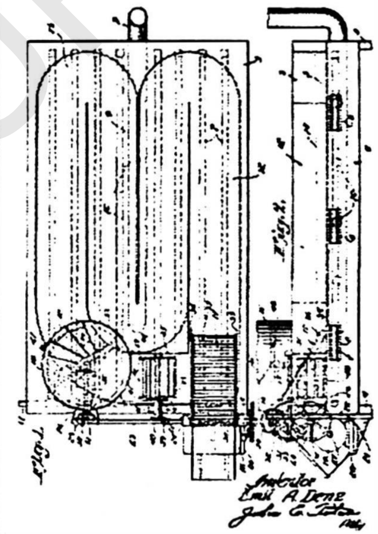
Table 2.2 Prior art and description of novel process or product

Patent requirements	CURRENT TECHNOLOGY Krispy Chips Machine	PRIOR TECNHOLOGY Food Slicer with Suction Device and Adjustable Cutting Surface (US20060283299A1)	PRIOR TECNHOLOGY Manual Fruit Slicer with Interchangable Cutting and Coring Disk (US200602254058A1)

Drawing	 	 	 

Patent requirements	CURRENT TECHNOLOGY	PRIOR TECNHOLOGY (US20060283299A1)	PRIOR TECNHOLOGY (US200602254058A1)
Novel process/ product	Krispy Chips Machine comprises of two feeders where a circular and a longitudinal feeders with load system, a push rod and a push plate included in each of the feeders, an adjustable cover plate attached on the longitudinal feeder, a rotary 3-blades cutting disc in the cutting chamber, a load system, an electric motor, a deep-fryer, a working table.	Food slicer comprises of - a platform pivotable on an end of the slicer, - a blade facing an end of the platform, - a handle that slides along a portion of the platform to raise and lower the end of the platform	A manual fruit slicer with interchangeable cutting and coring disks comprising a base and a disk. The base has a hollowed annular sleeve protruded out around its center with two laterally extended out jug-ears formed at both ends,
Inventive step 1. Cutting	- A rotary cutting disc with 3 blades is used in the present invention. The cutting disc is driven by motor through shaft where connected horizontally to the cutting disc - The removable blades boltly amounted on the surface of cutting disc having 30 degree inclined bevel at both right and left edges of the blade	- This invention used a blade that can fits under the front platform - The blade can be remove from the blade slot by exerts out the blade handle when desired - The slicer may be supplied with different type of blade to make different types of cut	- The invention used an annular slicing base with a hollowed coring circlet at its center and straight edges disposed axially between base and the coring circlet

Inventive step 2. Feeder	-The food solid is fed horizontally to the rotary cutting disc through round or longitudinal feeder which move towards the cutting disc by the load system due to the gravitational force -The longitudinal feeder is mounted with adjustable cover plate to get uniform thickness of food segment	N/A	N/A
Inventive step 3. Fryer	-The sliced food is cook or fried to produce snack by deep-fryer which located above the working cabinet and below the cutting segment to allow the sliced food fall into the hot edible oil in a deep-fryer - The temperature of the oil could be adjusted for appropriate temperature for frying	N/A	N/A
Industry application	For small scale industries	For kitchen used	For kitchen used

Patent requirements	PRIOR TECNHOLOGY Combination Food Processor and Fryer (US5289760A)	PRIOR TECNHOLOGY Potato Slicer (US4546684)	PRIOR TECNHOLOGY Potato Chips Frying Machine (US1520860)
Drawing	 	 	

Novel process/ product	The invention is about a motor-driven solid food processor and fryer that comprises of a housing,a chamber in housing,a cover for chamber, a feeding chute, two rotatable cutter blades , one is curved and the other is u-shape cutting edge at the surface of the cutting blade, a pusher paddle which spaced from cutting blade, a receptacle for cooking oil in housing, a removable perforated basket in receptacle provided with a cut-out portion in the front, a thermostat, an LED indicator, a spring load safety switch at the upper edge of the housing, a motor a plunger	The invention is about a potato slicing machine for use with a continuous fryer to produce potato chips that comprises of a housing having a top cover, a bottom cover, and upstanding side walls, , a rotatable circular wheel with a blade,a feed tube and a motor	The invention is about a potato chip frying machine that will slice and fry potato-chips in a continuous process which mainly comprises of a rectangular tank having a horizontal partition comprise of below and above compartment,a cooking compartment above and heating compartment below the partition, a series of gas burners distributed underneath the bottom, and an exhaust flue having openings along its length and extending longitudinally underneath the middle portion of the bottom partition

Inventive step 1. Cutting	This invention used two types of blades which positioned above pusher paddle, whereby driven by motor through shaft and gear which shaft is connected vertically to the cutter blade to cut food segments fall by gravity - First cutting blade having slightly raised curved cutting edges while second having u-shaped cutting edges	A rotatable circular fly wheel with a blade is used in the invention below the bottom cover at base of the device which driven by motor through shaft which shaft is connected vertically to the fly wheel - The blade is mounted in a V-shaped recess on the upper surface of fly wheel and held in place by removable plate	In the potato frying machine, a cutter disc is used having a plurality of knives operating through driven motor by a gear connection from the shaft, and mounted for horizontal rotation directly below the bottom opening of hopper - Knives are oppositely disposed
Inventive step 2. Feeder	The food solid is inserted vertically through the cylindrical chamber to the cutter blade - The feed tube could be inserted with a plunger in order to force the whole solid food items against the rotating cutting blade	The potato is inserted vertically to the fly wheel through feed tube whereby the food solid is fed by hand or a hopper -The feed tube terminates in an expanded elliptical portion and is mounted on a bottom cover surrounding an exit port in cover	The potato chip frying machine having a removable circular hopper on the top of the tank - The hopper has a sloping bottom which converges into the bottom opening located directly over the continuous twist and turns channel
Inventive step 3. Fryer	N/A	N/A	N/A
Industry application	For small scale industries	For small scale industries	For small scale industries

2.5 Review of slicer machine in market

There are not many banana slicer machines in the market that can produce longitudinal banana slices. Most of the machines that found related in producing banana slices in market are functioned for producing banana slices in circular shape. Since the demand of the longitudinal banana chips is increase in market, banana slicer machine that can produce longitudinal banana slices is needed as substitution to the manual method of longitudinal banana slices.

There are few of banana slicing machine found in the market currently but not fabricated in Malaysia. These machines are made in France, Nigeria and China where the technology of these countries in producing banana slices is apparently more advanced.

2.5.1 Tefal MB750 Slicer from France

Tefal MB750 is a product brand from Tefal which made from France that can be used to slice any solid food from vegetables, fruits, cheese and others. The food solid can be sliced by placing the food through the vertical hopper to a rotary drum that connected to the motor (not shown) as shown in Figure 2.1.

This machine comprised of five drums for five different usages which are thick slice, thin slice, thick shred, thin shred and grate as shown in Figure 2.2. The drum is driven by a 150 watt power of motor. The dimension of the slicer is approximately 28 x 16 x 28 cm with weight of 14 kg.

Figure 2.1 Operation of the slicer

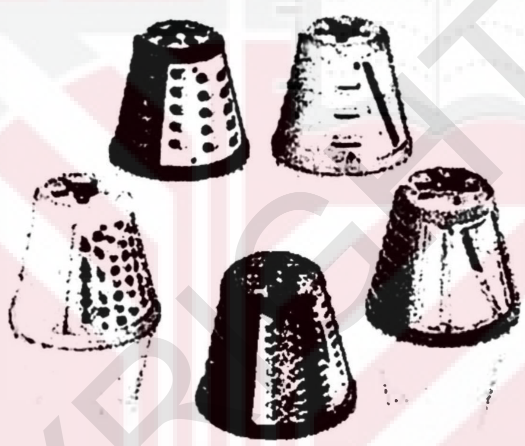


Figure 2.2 Five different types of drum

The advantage of this slicer is it can slice banana into circular shape of slices. It can form variety shapes and sizes of slices food. Other than that, the hopper and the drum are detachable and easy to clean. Figure 2.3 shows parts of the slicing machine that have been detached.

Figure 2.3 Parts of the Tefal slicing machine

The disadvantage of this machine is the hopper is small which means the food needs to be cut to fit the small hopper. Besides that, the thickness of the food slices cannot be adjusted wherein the cutter of the drums have fixed size. Furthermore, the machine is time consuming where users need to keep on pressing the button while placing the food inside the hopper to ensure the food is sliced. This machine also produce sound which is noisy that come from the motor.

2.5.2 Plantain slicer machine from Nigeria

The machine that invented from Nigeria is used to slice banana for banana chips production which comprised of two-rotary cutting disc to cut the banana. The banana is amounted to the cutting device through a feeding chute that oriented perpendicularly to the rotary cutting device. The cutting disc is connected to the motor by pulley and shaft and powered by 1hp electric motor. The machine that has dimension of 790 mm (length) x 470 mm (width) x 820 mm (high) with capacity of 50 g/s can produce uniform slice thickness of 2.9-3.20 mm. This machine can only produce circular banana slices. Figure 2.10 shows the view of the plantain slicer.

Figure 2.4 Pictorial view plantain slicer (Source: Akande & Onifade, 2015)

The advantage of this machine is it has ability to slice efficiently depends on the mass of the plantain and the power rating of electric motor. This can be indicated when the slicing blade rotated without wobbling, the output of motorized slicer was quite encouraging and saved time. Other than that, no discoloration happen during slicing process and can prevent contamination. The disadvantage of this machine it cannot produce longitudinal banana slices.

2.5.3 Banana chips cutting machine from China

Banana chips cutting machine is made from China that has dimension of 800mm (length) x 550mm (width) x 1300mm (height). It has weight of 60 g and can produce uniform thickness banana ranging from 0.2mm to 8 mm.

It comprised of seven different sizes of hoppers. Banana is subjected perpendicularly to the cutting device through the hoppers. The slices banana are discharged out from the machine through the discharge unit.

Figure 2.5 View of top machine

Figure 2.6 View of side machine

Figure 2.7 View of front machine

The advantages of this machine it can slice banana in various different size of circular banana. The capacity of the machine is high which is 50 000 pieces per minute. Besides that, it is easy to operate and save electricity. The disadvantage of this machine is it cannot produce longitudinal banana slices.

CHAPTER 3

METHODOLOGY

3.1 Flow Diagram of Design Process

The chronology of the machine design flow will be discussed in this chapter. The project methodology used the flow diagram as guideline and project management. In order to replace the manual production of producing longitudinal banana chips, some considerations and assumptions are being stressed and re-examine to ensure the machine fabrication meet the specification and the objectives of this project. The following Figure 3.1 shows the flow diagram of the design process.

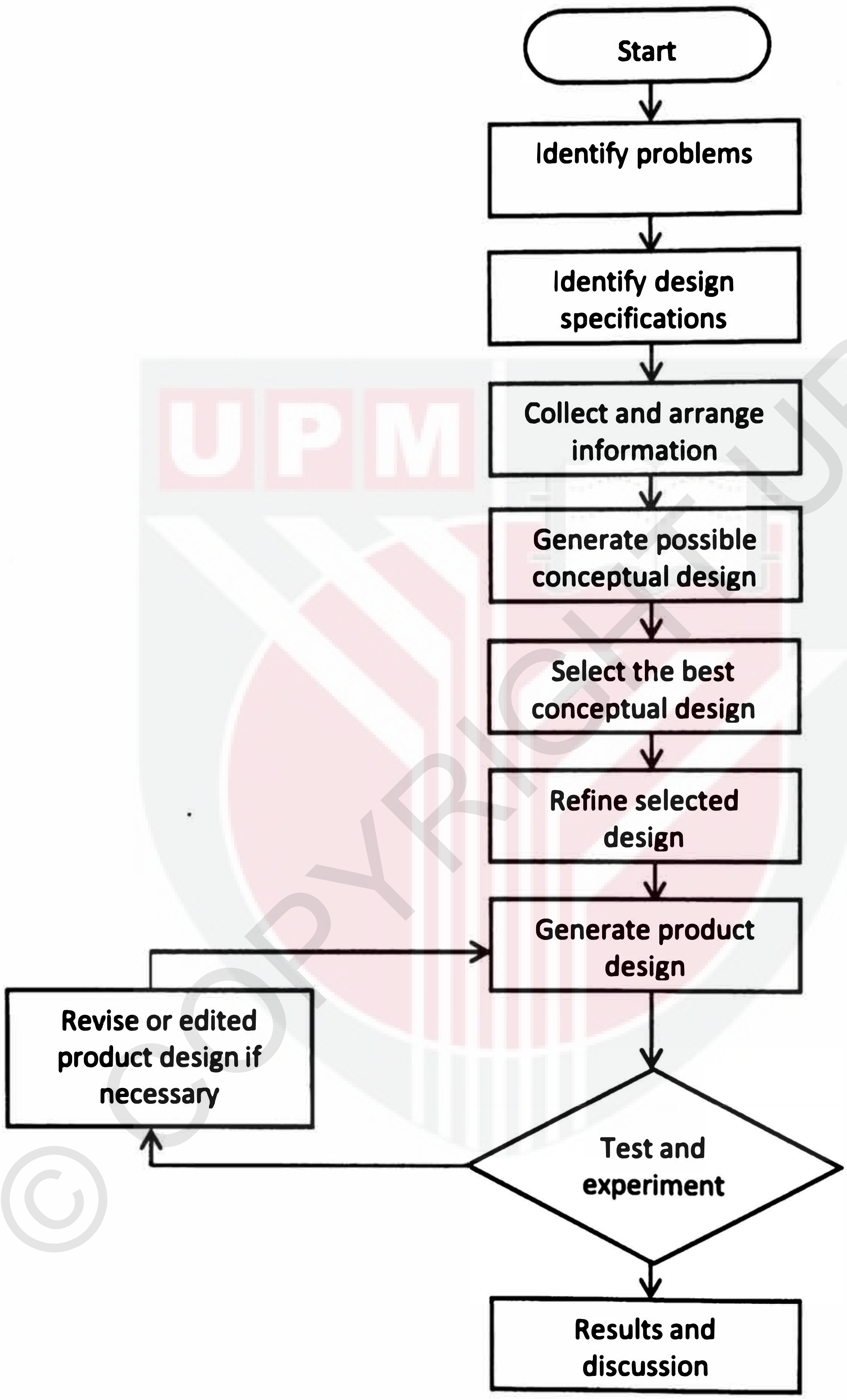


Figure 3.1 Flow diagram of design process

Identifying problems faced by the entrepreneurs in banana chips manufacturers is the first thing that has been considered. A visit to FAZ Enterprise has been made to observe the method used to produce banana chips and main problem is identified. New invention on banana slicer to slice banana in longitudinal shape is needed to replace the manual method used. After that, design specifications were then drafted. The design specifications were then finalized as the design objectives and the component parts of the machine were identified for the idea generation of machine mechanism.

Next, the information on prior arts through patent search was compared. The purpose of the patent search is to determine whether any prior art patents or other publications existed are not similar with the machine being invented. The advantages and disadvantages of the current machine were studied through the comparison to assist idea generation for conceptual design.

A new concept of banana slicer was designed to solve the problem and this is crucial step in any design machine where the idea generated in mind need to be transformed into visualized reality. All the conceptual designs were compared against one other based on certain important criteria. Pugh concept selection matrix and concept scoring matrix were used as evaluation tools. The most satisfied concept that has all criteria needed is selected as the best design. The best design then continued to next stage of development to be improved. The most suitable position and shape of the feeder to produce longitudinal banana slices is identified. Other than that, appropriate cutting device and blade also is identified by considering the thickness and appearance required by the entrepreneurs.

After the generation of the design concept and mechanism used for the machine, refinement of the selected design concept and mechanism used was done. In this step, the design is simplified as much as possible to reduce the cost of production so that the machine is affordable. Cost effective and suitable materials were selected for all component parts. Then, detailed dimension drawing, bill of material, and installation procedure were prepared. The prototype of the machine then can be fabricated and build.

Drawing is prepared completely using AutoCAD 2015 software. All the part components and dimensions of the machine are labeled. The drawing is send to selected fabricator to be fabricated. Discussion is held to determine the workability of the design drawing. After both sides agreed, the design is proceed to fabricate. Testing on the machine is important to determine the performance of the machine, and to identify whether the requirement needed successfully attempt after the machine is fabricated. Testing on the machine is done at laboratory. The machine is test using banana and other food products such as cassava, sweet potato and carrot. Since the uniformity of slicing in longitudinal in shape was not fully achieved, the machine is modified by placing the adjustable cover plate on the longitudinal feeder. The performance of the machine is tested again and discussion on the results obtained is made.

3.2 Conceptual Design

The general objective of this research project was to design and fabricate banana slicer machine that can slice banana direct to fryer for banana chips production. The development of this machine was conducted in a systematic order methodology to ensure the end product is well accepted by the entrepreneurs of banana chips manufacturer from SMEs.

The design and fabrication of banana slicer machine includes component design as follow:

- Feeding mechanism
- Cutting mechanism
- Frying mechanism.

There are three drawing concepts were developed in considering the need of banana slicer machine. These drawing were the first ideas on how the machine will be. After evaluating all the parameter involved, the best design is selected for fabrication. The details of the requirement of conceptual design are shown in Table 3.1 below.

Table 3.1 Requirements of conceptual design

No.	Requirements	Details
1	Objective of the project	The purpose of the conceptual design is to generate design ideas for banana slicer machine direct to fryer for production of banana chips where the machine can produce longitudinal slices of banana
2	Originality of the idea	Observing the existed slicer machine and other method or equipment related to the banana

		slicer machine with no intention to copy
3	Knowledge and facilities	Drawing knowledge and Autodesk software
4	Drawing explanation	All details and explanation of the drawing concepts must be given
6	Numbering	Each drawing concept must be numbered and labeled accordingly

3.2.1 Conceptual design 'A'

Concept design A comprise of two longitudinal feeders and two circular feeders. The feeder is subjected vertically to the cutting disc that comprised of one blade. The rotary cutting disc is driven by motor that connected below the cutting disc as shown Figure 3.4. The declined discharge unit is placed below the cutting and feeding mechanism to allow the slices banana fall into the fryer. The advantage of this design is it is simple to fabricate and cost effective as it requires less material. The disadvantage of this machine is it is not suitable for produce longitudinal banana slices and has high possibility in producing ununiformed thickness of longitudinal banana slices.

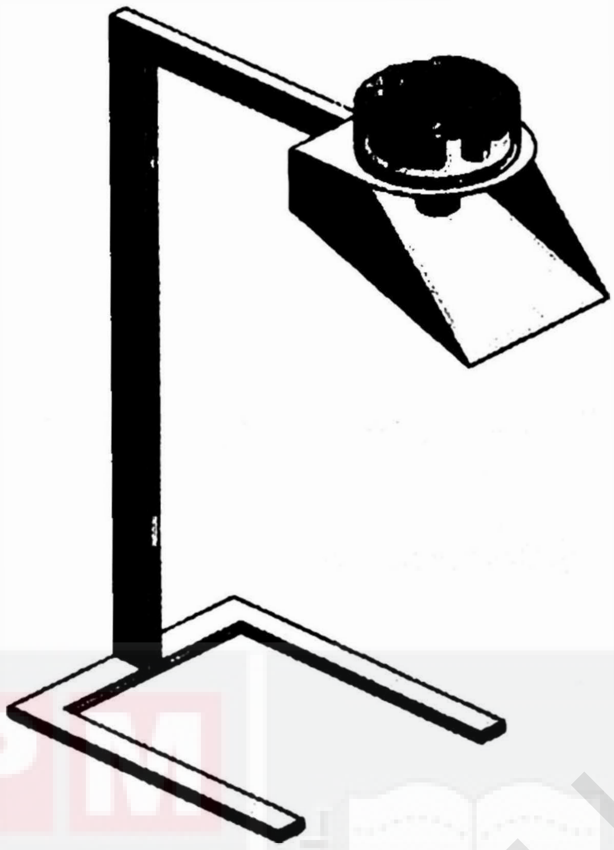


Figure 3.2 Concept design A

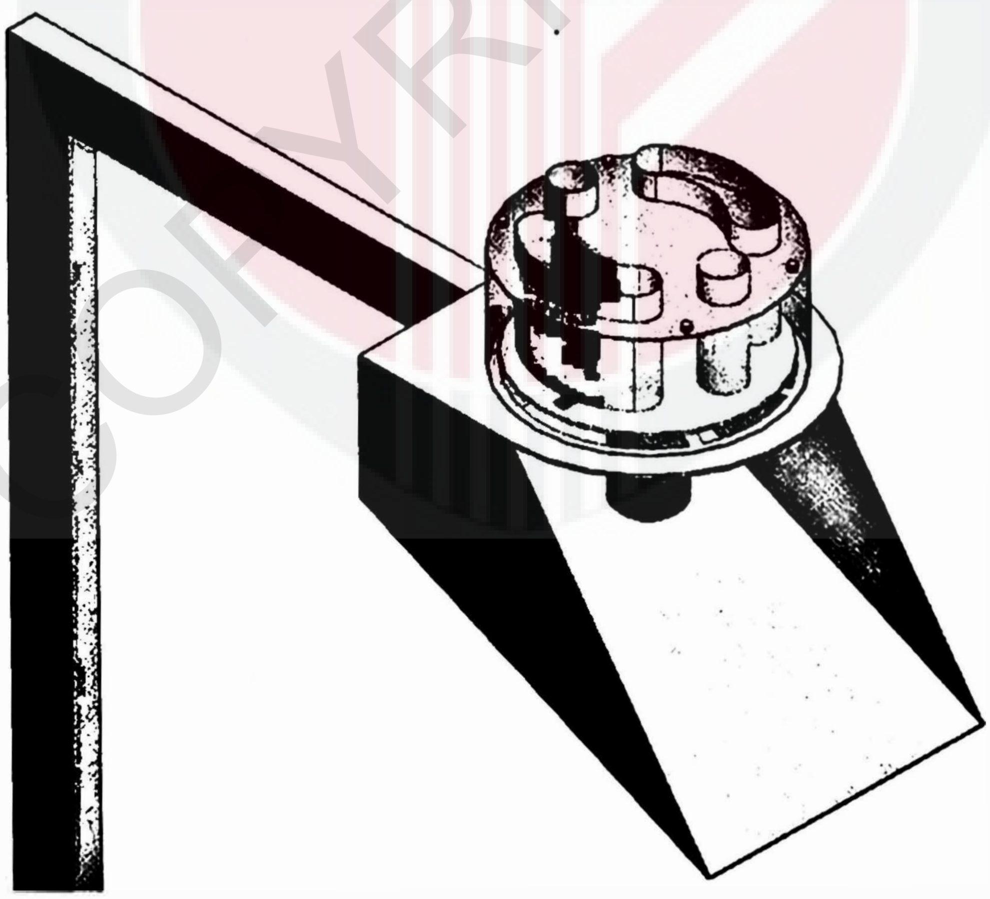


Figure 3.3 Close view of concept design A

Figure 3.4 Back view of design A

3.2.2 Conceptual design 'B'

In concept design B, the orientation of feeder and cutting disc are change where they are designed to have horizontal orientation as shown in Figure 3.5. Other than that, the number of feeder is reduced for ergonomic purpose. At feeder, pusher is designed to force the banana into cutting disc that comprised of three blades. The number of blade is improved from one to three blades due to disability of the blade to cut the banana with thickness required and enhance the capacity. One rotation of a blade can cut a slice of banana compared to one rotation of three blades that cut three slices of banana. Therefore, the capacity produce by design B is 3 times greater than design A. The advantage of this machine is it has high possibility in producing uniform thickness of longitudinal banana slices and disadvantage of this machine is the slicing efficiency of producing circular banana may low. Besides that, this designed may has potential to cause hazard.

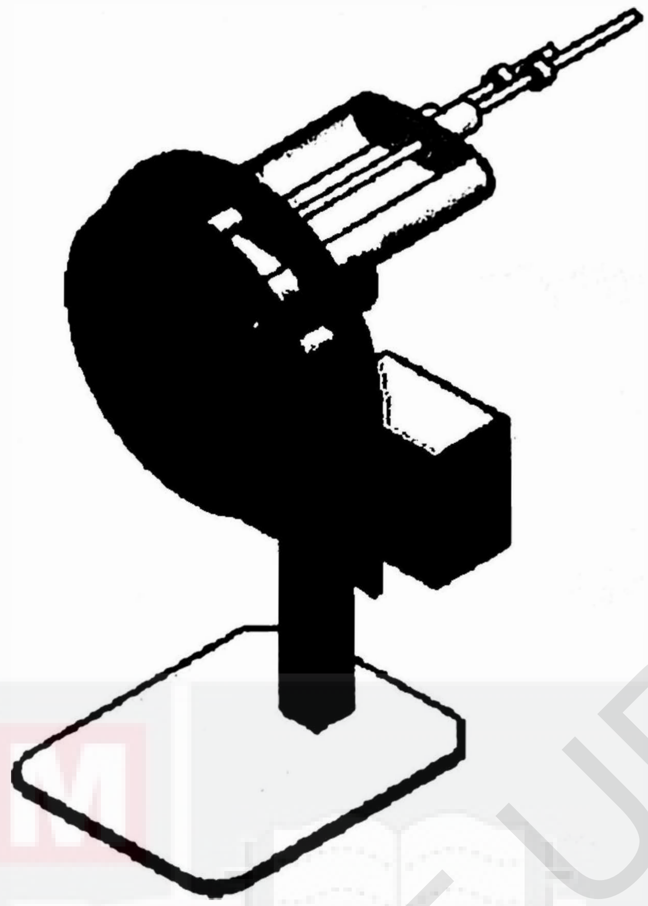


Figure 3.5 Concept design B

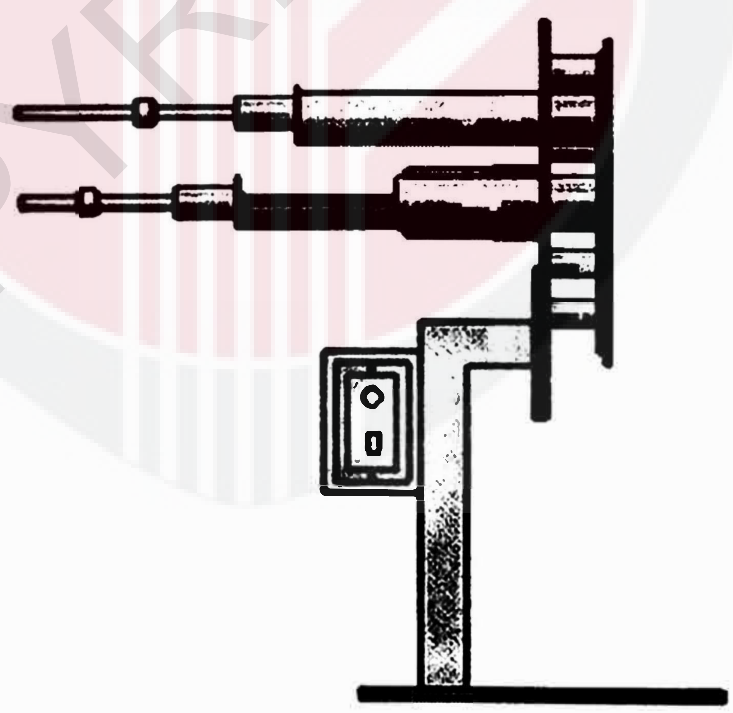


Figure 3.6 Side view design B

3.2.3 Conceptual Design 'C'

Design C is improved from designed B where the machine is designed to be semi-automatic which load system is designed as shown in Figure 3.8 for feeding mechanism, and working cabinet to place a deep-fryer for frying purpose and storage. Other than that, cutting mechanism is also improved by designed cutting chamber with safety cover to house the cutting disc that is added with three blades. The advantage of this machine is it may reduce the man power of handling the machine which is it is designed as semi-automatic machine where the load system helps to give force to the feeders to move towards cutting disc. The man power is only needed to manually loaded the banana into the feeder. This machine is also more safe to use where the cutting chamber and safety cover is added to house the cutting disc to prevent the exposure of the blades at the cutting disc to the user during the process of the machine. Lastly, the machine is more easy to use and portable with the presence of working cabinet and caster wheels. The working cabinet can be used to store tools, spare parts, deep fryer and the disassemble components of the machine after used. Meanwhile, caster wheel is designed for easily carry the machine from one place to another place. The disadvantage of this machine is has more components and costing of fabrication is more higher than design A and B.

Figure 3.7 Conceptual design C

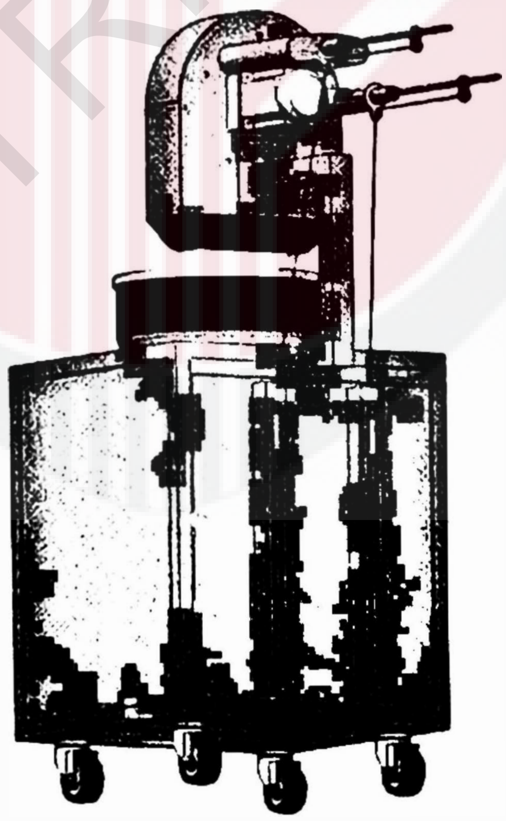


Figure 3.8 Back view design C

3.2.4 Conceptual Evaluation and Selection

From the four concepts of drawings that were developed in designing the banana slicer machine, the best design needs to be selected. Therefore, structured method of concept selection is conducted. There are two stages of conceptual selection which is the first stage is to eliminate the product concept idea generated from many to a relative few that will get additional refinement. At second stage, the remaining concept design is evaluated to select final concept design. Some selection criteria and the description used for concept screening and concept scoring are shown in Table 3.2.

Table 3.2 Description of the criteria used in conceptual evaluation

No	Citeria	Description
1	Ergonomics	The machine should consider of the most comfortable positions when handling the machine.
2	Consistency	The thickness of the slices banana produce should be ranging from 1.0 mm to 1.2 mm by the cutting disc
3	Effectiveness	The capacity of the machine should be better than manual method.
4	User friendly	The machine should be convenient to use especially aspect of operation handling.
5	Maintenance	Parts of the machine can be reached or detached easily for cleaning purpose.
6	Lifecycle	The machine should resist corrosion and able to use for long period.
7	Size/ portability	The size of the machine aims to be lightweight, compact and easy to transport.
8	Affordability	Material cost, manufacturing cost and assemble cost must be affordable for the targeted customer.
9	Safety	The machine must be safe to be handled by operator/user which means safety features should be installed at potential hazardous parts.
10	Multi-functional	The machine should be able to produce longitudinal and circular banana slices, and blade of cutting disc must be able to slice various different of food solid.
11	Exchangeable	The blades should be able to replace in case of blunt or

	parts	replace with other appropriate blades for purpose of grating, shearing, shaving and others.

3.2.5 Concept screening

Pugh Concept Selection which also known as matrix method was used for concept screening. It is used as a decision making model to choose between a list of alternatives. The most important criteria in the decision are chosen, and the alternatives are compared using these criteria. Figure 3.9 shows the steps to construct decisional matrix for concept screening. Additionally, Table 3.3 shows the description for Figure 3.11 the step in constructing the concept screening method.

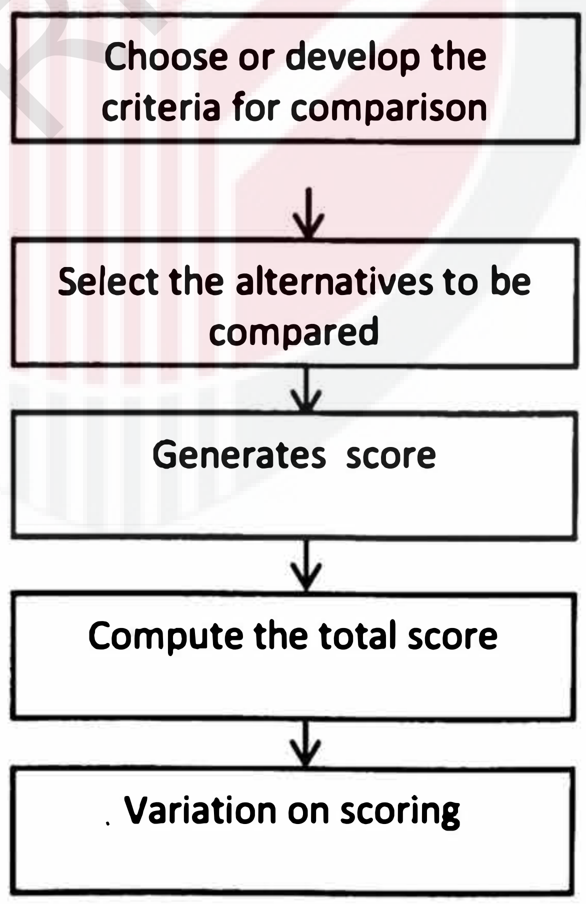


Figure 3.9 Steps to construct decision-matrix

Table 3.3 Description of every step in constructing decisional matrix (Source: O. de Weck, 2015)

Step	Explanation
Choose or develop criteria for comparison	Customer requirement are examined. A set of engineering requirements and targets are generated.
Select alternative to be compared	The alternative ore the different idea developed during concept generation. All concepts should be compared at the same level of generalization and in similar language.
Generate score	One of the concept will be used as datum, with all the other being compared to measure by each of the customer requirement. For every comparison, the product should be evaluated as being better (+), same (S), or worse (-). For rating +1, 0 or 1 can be used. If it impossible to make a comparison, more information should be developed.
Compute the total score	The score will be generated. The overall total is the number of plus score deduct the number of minus score. The total should be not treated as absolute in the decision-making process but as a guidance only. The top two score that are very close or very similar then should be examine closely to make more informed decision.
Variation on scoring	A number of variation on scoring exist and can be used as finer scoring system. However, it is not compulsory in this concept selection as selected concept design will proceed to the next stage, concept scoring matrix.

Design concept 'A", 'B', 'C', and 'D' were tabulated in spreadsheet and compared using decisional matrix concept screening method. Design concept 'A' was chosen as datum, as a reference comparison. High rang design concept with positive overall score were choose to proceed to the next stage, the concept scoring. Based on Table 3.4 design concept 'B' and 'C' ranked the top two score therefore selected to proceed the scoring stage.

Table 3.4 Comparison of design concept using decisional matrix method

Criteria	Design Concept		
	'A'	'B'	'C'
Ergonomics		+	+
Consistency		-	+
Effectiveness		-	+
User friendly	D	-	+
Maintenance	A	+	+
Lifecycle	T	S	S
Size/ portability	U	+	+
Affordability	M	S	-
Safety		S	+
Multi-functional		S	S
Exchangeable parts		+	+
Total +		4	9
Total -		3	1
Total S		4	2
Overall score		1	8
Rank		2	1
Continue to next stage	No	Yes	Yes

3.2.6 Concept Scoring Matrix

Scoring is more careful analysis of relative few concepts in order to choose the single concept which can make product success is possible. Increased resolution differentiates better competing concepts. Figure 3.10 shows the steps to construct concept scoring matrix, and Table 3.4 shows the description of Figure 3.10; the steps in constructing the concept scoring method.

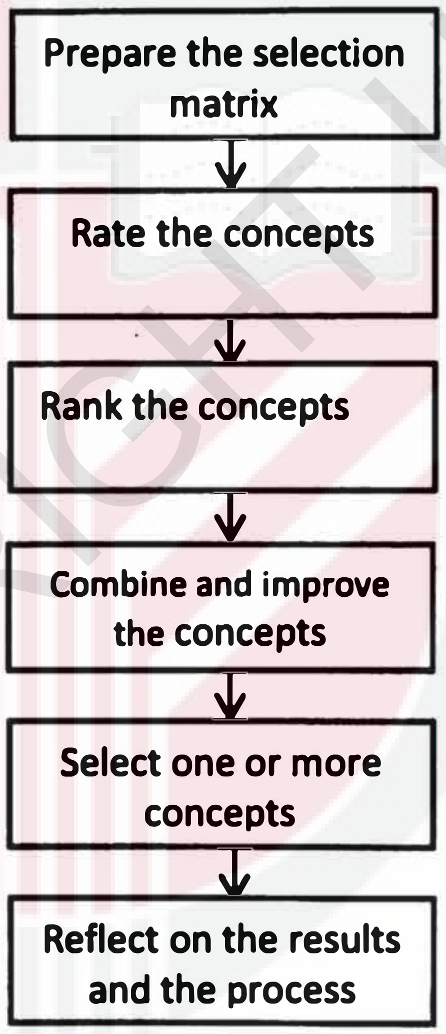


Figure 3.10 Steps to construct concept scoring matrix

Table 3.5 Description on every step in constructing concept scoring (Source: Nanyang Technology University, 2014)

Step	Explanation
Prepare the selection matrix	The use of hierarchical relation is helpful to illuminate the criteria. After the criteria are entered, importance weights are added to the matrix. Several different schemes can be added to weigh the criteria, such as assigning an importance value from 1 to 5, or allocating 100 percentage points among them
Rate the concepts	Recommended scale is from 1 to 5 1-Very bad 2-Bad 3-Average 4-Good 5-Very good
Rank the concepts	Once the rating is entered for every concept, weighted scores are calculated by multiplying the raw score by the criteria heights. The total score for each concept is the sum of the weighted score. $$S_j \sum_{i=1}^{n} r_{ij} w_i$$ Where $r_{ij=}$ rating of concept j for the i^{th} criteria w_i = weighting for i^{th} criteria n=number of criteria S_j =total score of concept j
Combine and improve concepts	Look for combination or changes that improve concepts.
Select one or more concepts	The final selection is the concept that the highest ranking and evaluated by sensitivity analysis. Two or more scoring

	matrices with different weighting can be tabulate to yield the concept ranking for various market segments with different customer preferences.
Reflect on the result and the process	Selected conceptual design will be modified to improve performance. The product will be further refined for low production cost

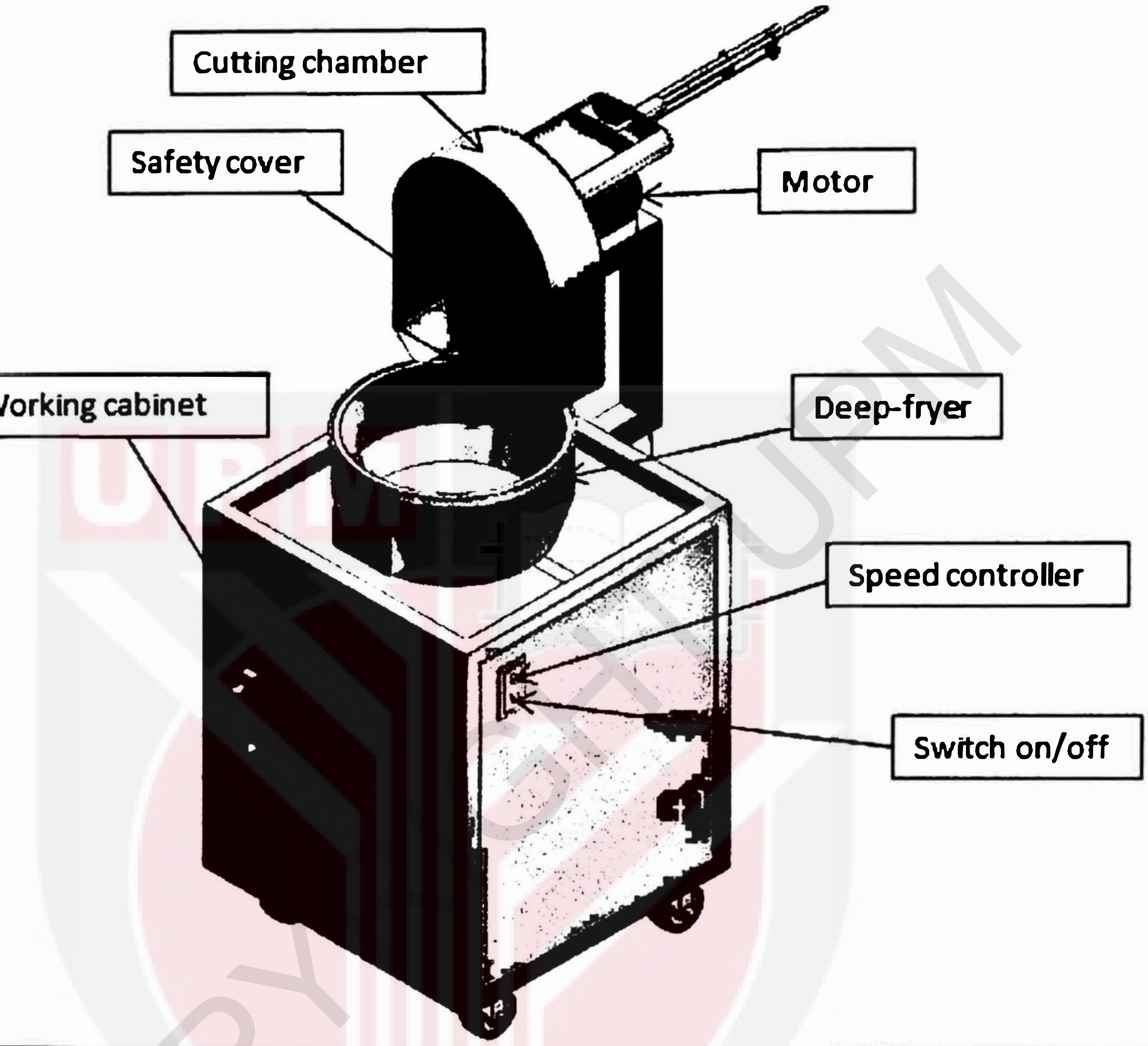
Design 'B' and 'C' which passed the decision matrix method in concept screening were tabulated in a spreadsheet. All the criteria were weight for the importance and significance. Ergonomic, consistency, effectiveness, size/ portability, safety, maintenance and affordability are the most crucial factors, follow by lifecycle, multifunctional, exchangeable parts and also user friendly. Weighted scores were than summed up to get the total score. Design concept with the highest total score was selected as the best conceptual design. Next, the best conceptual design was improved and refined as final design of the machine.

Table 3.6: Selection of the best conceptual design using concept scoring

Criteria	Weight (%)	Design concept			
		'B'		'C'	
		Rating	Weighted score	Rating	Weighted score
Ergonomics	15	4	12	4	12
Consistency	15	2	6	3	9
Effectiveness	15	2	6	4	12
User friendly	10	4	8	5	10
Maintenance	15	4	12	3	12
Lifecycle	10	3	6	4	8
Size/ portability	15	3	9	4	12
Affordability	15	4	12	3	9
Safety	15	2	6	4	12
Multi-functional	10	5	10	5	10
Exchangeable parts	10	2	4	4	8
Total score			91		114
Rank			2		1
Continue to next stage			No		Yes

Concept C has higher score compared to the concept C. Thus, concept design C is selected as the final concept design. The best conceptual design of banana slicer machine is refined and improved using Autodesk software.

3.3 Construction and Structure of Banana Slicer Machine



(a)

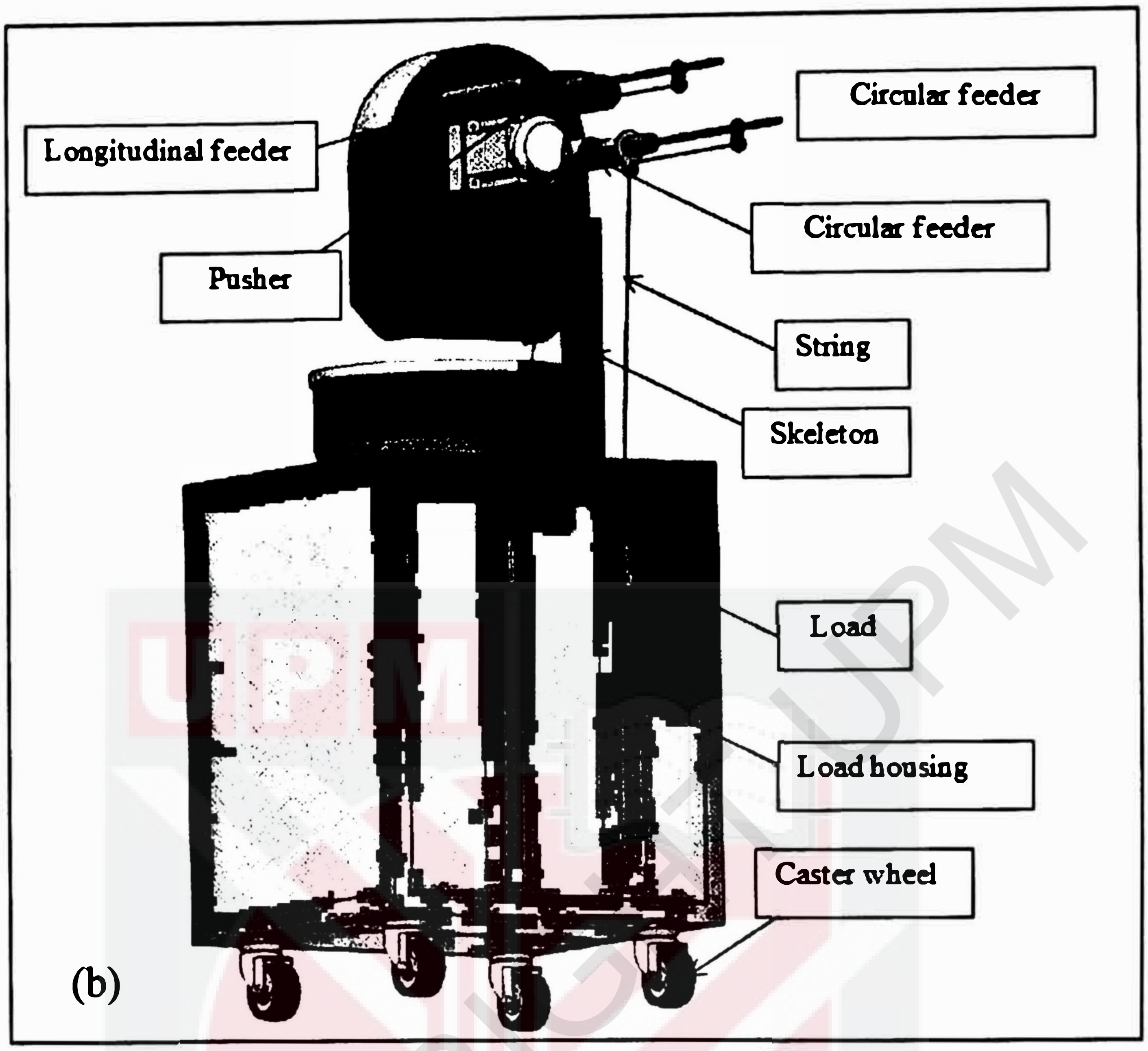


Figure 3.11 View of (a) front side and (b) back side of fully assemble banana slicer machine with label of components

Figure 3.11 shows above, the banana slicer machine that is developed by using the Autodesk software. The dimension of the machine is 0.97 m (length) x 0.5 m (width) x 1.24 m (height). Basically, the main components of the invention are motor, feeding mechanism comprised of longitudinal and circular feeder with pushers and load system, cutting mechanis comprised of cutting chamber, rotary cutting disc and safety cover, deep-fryer and working cabinet connected with the load system. The detailed of design drawings are illustrated in Appendix A. In further details, the function of all main components of the machine will be discussed in details in the further sections.

3.3.1 Motor

The motor used to supply mechanical energy to drive the rotary cutting in this machine is electric motor speed controller with electromagnetic brake. The selection of motor is due to some reasons which are:

- It has wide range of variable speed which is adjustable by using speed controller
- It has variable selection of speed such as normal or reversible, slower starting slower speed reduction and others
- A constant rpm can be obtained even if there is any frequency variation, and
- always maintain the load properly where loading can be kept normally by the brake whenever the power source is shut down.

There are few aspects need to be considered in selecting motor. The first aspect to be considered is type of power available. This machine is designed to be used in small scale industries, thus single phase motor should be used as the power requirement can be easily met such as voltage. The motor can supply 240 V AC which is appropriate with the machine requirement.

Next, the second aspect need to be considered is the size of motor. Normally, motor is rated in Horsepower (Hp) or (W) and it's referring to the power that the motor will develop when it is turning at full speed. Other than that, the starting load also must be taken into account. Motor selected must produce adequate starting torque to start the load. Speed requirement of the motor also should be consider in select the right motor.

The electric motor used in this machine is model of M540-402. It is connected to the motor base and cutting chamber and rotary cutting disc via coupling and shaft. Figure 3.12 shows the location of the motor in the machine, while the details specifications of the motor are shown in Table 3.6.

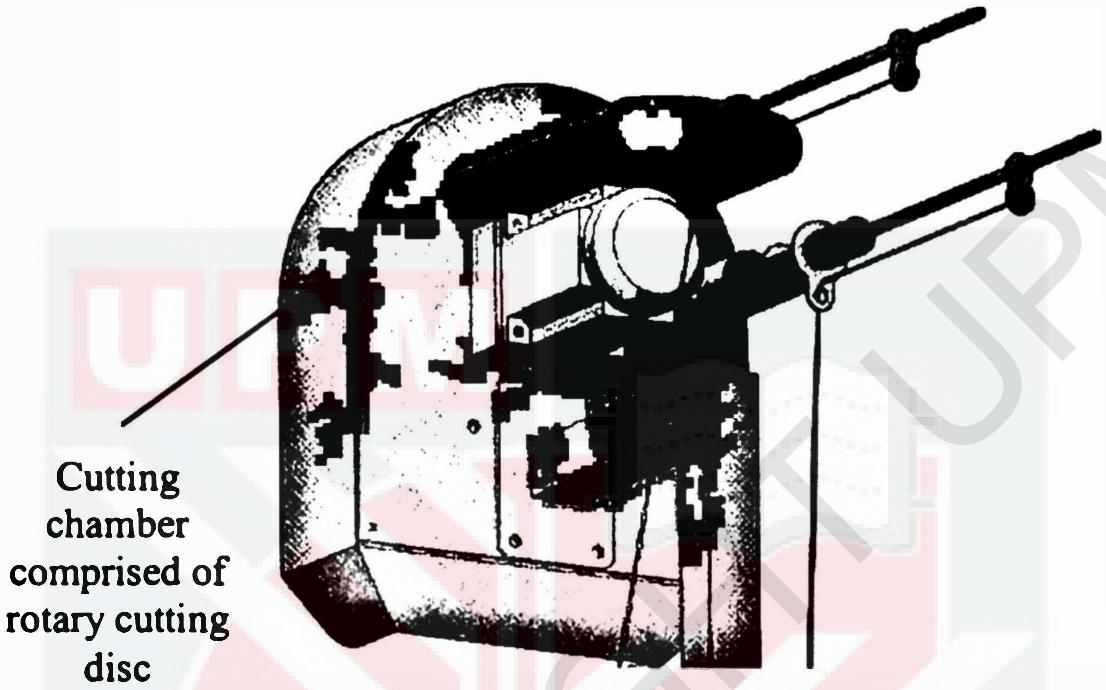


Figure 3.12 Position of motor in schematic diagram

Figure 3.13 Back view of the motor

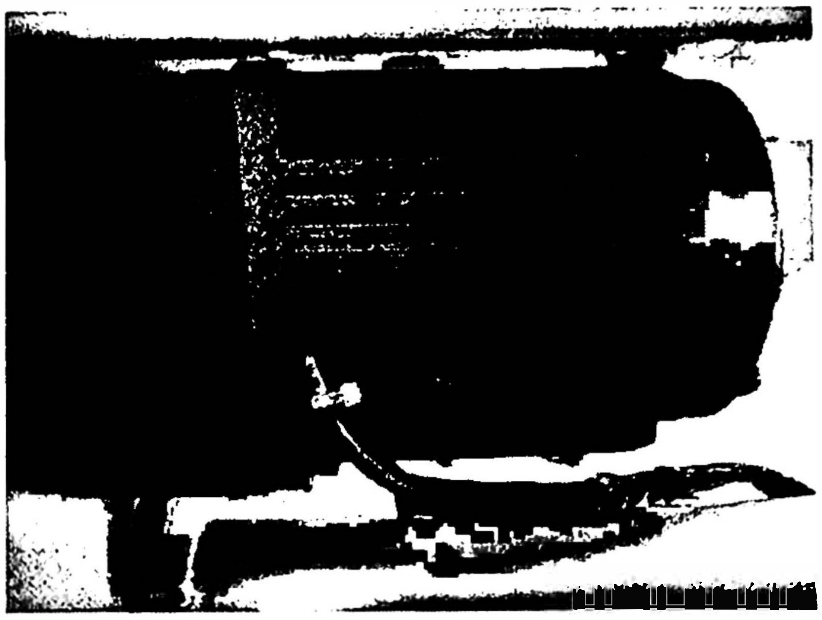


Figure 3.14 Side view of the motor

Figure 3.15 The motor tag

Table 3.6 Detail specifications of the motor

Description	
Type	Stepless variable speed motor
Dimension	90mm
Horsepower	40 W (1/19 Hp)
Speed	50 Hz:90~1400rpm; 60 Hz: 90~1700rpm
Capacitance	2.5 μF
Voltage	240 V
Output shaft motor	Straight tooth shaft
Type of power	Single phase
Function	With electronic brake

3.3.2 Feeding mechanism

3.3.2.1 Feeder

Feeder is where banana is amounted in the machine to be conveyed to the cutting disc to be sliced. The feeder is designed to be oriented horizontally to the cutting disc to avoid the banana from overlap during the slicing process. Stainless steel is selected as material fabrication of the feeder for hygienic purpose and food grade standard material. There are two feeders are used which are circular and longitudinal feeders. Both feeders are attached perpendicularly to the cutting chamber as shows in Figure 3.16 and detailed design drawing is illustrated in Appendix B. Circular feeder is used to amount banana vertically to the cutting disc for producing circular banana slices, while longitudinal feeder is used to amount banana horizontally for producing longitudinal banana slices and vertically for circular slices. Table 3.7 below shows the details specification for both feeders. Averagely, the feeder is able to hold up to eight number of tubers of banana for longitudinal feeder and three for circular feeder to be sliced at one time depends on the size of the banana.

Table 3.7 Details specification of the feeders

Descriptions		
Type	Longitudinal feeder	Circular feeder
Function	Amounting banana horizontally and vertically to the cutting disc	Amounting banana vertically to the cutting disc
Dimension	Length: 341 mm Width: 107mm	Length: 291 mm Diameter: 42 mm
Number of loading	Can hold up to 8 number of tubers of banana	Can hold up to 3 number of tubers of banana

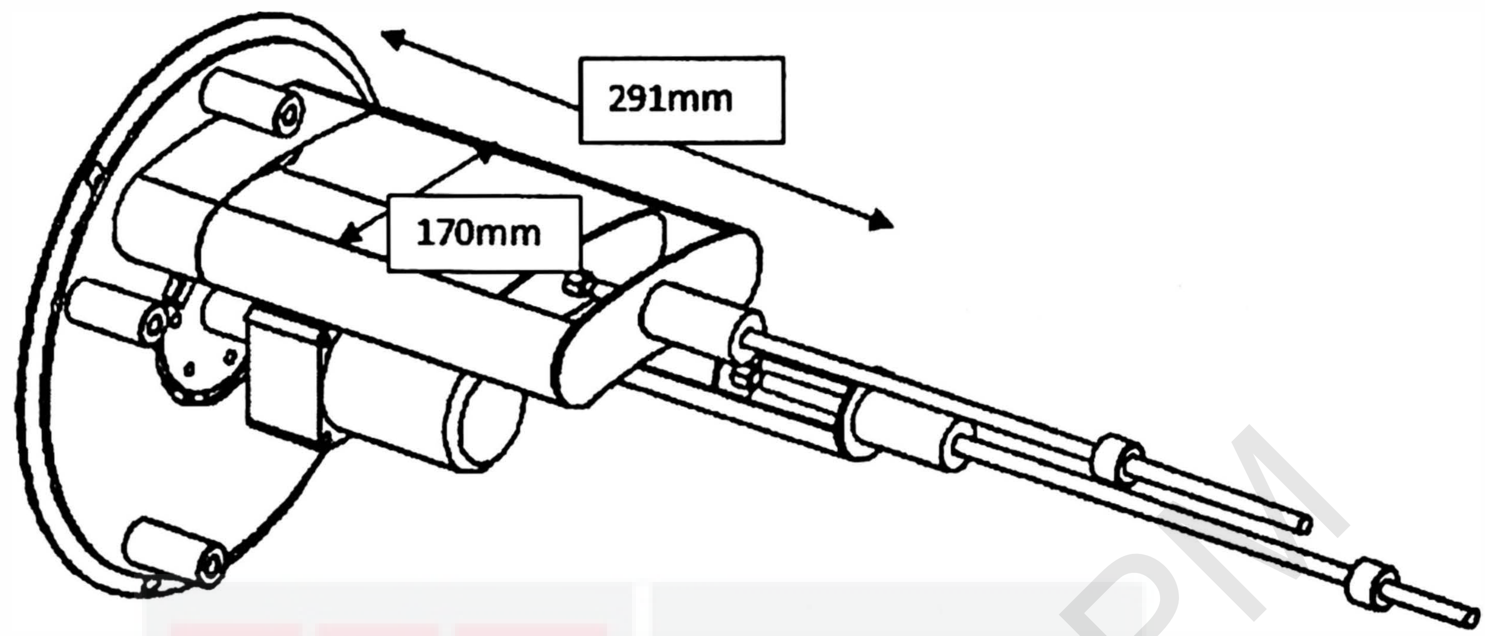


Figure 3.16 Schematic diagram of feeding mechanism

Figure 3.17 Real view of the feeding mechanism

3.3.2.2 Pusher

Each of the feeder comprised of pusher as shown in Figure 3.18 which functioned to drive the banana toward the cutting disc. Each pusher comprised push lid and push plate. Push plate for longitudinal pusher has length of 143mm and height of while circular pusher has length and height of 41mm. Both push lids have same dimension which are 415mm that each of them is attached with small irregular oval-like shape plate. There is a hole at each of the small plate where place for ligament of string of the load system. Details design drawing of pushers is illustrated in Appendix C.

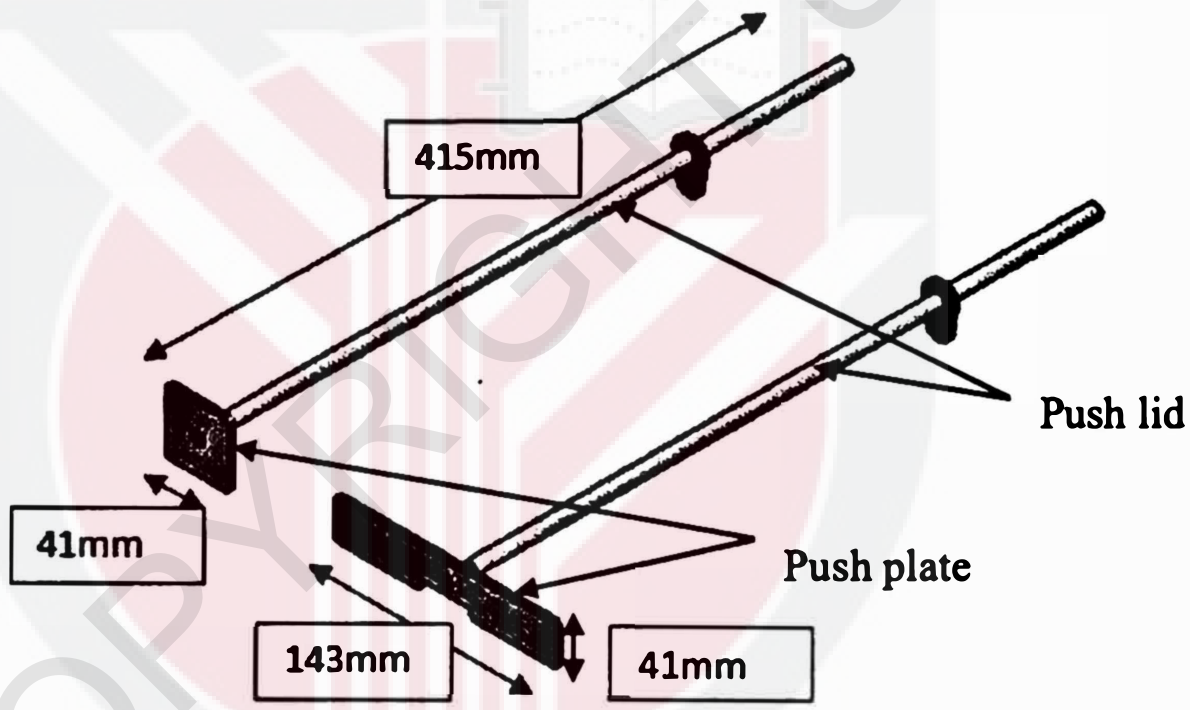


Figure 3.18 Pusher for longitudinal and circular feeder

3.3.2.3 Working cabinet

The working cabinet in this machine is used as part of the load system, wherein two loads that each placed in housing that made from hollow steel that each has length of 50mm are amounted at the back of working cabinet, and connected to the pushers via nylon string that has length of 1200m and thickness of 2mm. Figure 3.19 shows schematic diagram of the load system. In order to move the pusher towards the cutting disc, load system is applied in the present invention where the load system is defined to give driving force to the pusher to drive the food solid amounted on the feeder to the rotary cutting disc. The string that connected to the pusher is made up from nylon thread which able to hold 1 kg of load for each pusher.

The working cabinet has dimension of 50mm (length) x 50mm (width) x 60mm (height) as shown in Figure 3.19 and also used to place a deep-fryer on the top surface of the working cabinet for frying purpose as shown in Figure 3.20 below. The appropriate deep-fryer should have diameter of 370mm (length) x 200mm (width) x 250mm (height) which is standard dimension of multi cooker in market. Detail design drawing of working cabinet is illustrated in Appendix D.

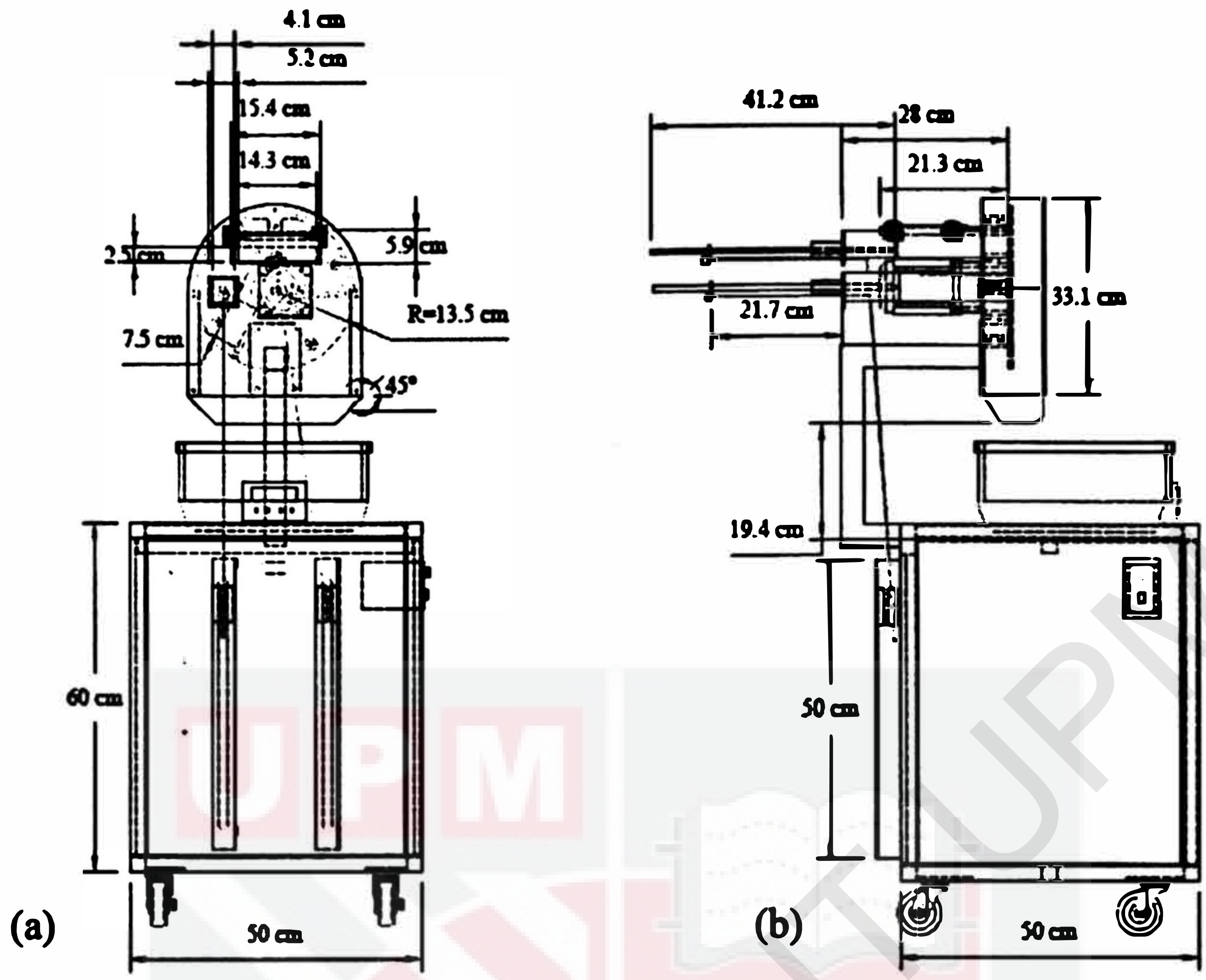


Figure 3.19 (a) Schematic diagram of load system that placed at the back of the machine

(b) Schematic diagramof load system from side view

Figure 3.20 Real view of load system at the back of the machine

3.3.3 Cutting mechanism

3.3.3.1 Cutting chamber

Cutting chamber as shown in Figure 3.22 is functioned to house the rotary cutting disc and urge the banana slices to the deep-fryer through the discharged unit. The cutting chamber is made up from steel plate as well with the dimension of 101mm(width) and 380mm (height) as shown in Figure 3.21. The cutting chamber is also designed with transparent safety cover which could be detached by removing the screws attached for safety purpose that made up from Perspex acrylic sheet. Detail design drawing of cutting chamber is illustrated in Appendix E.

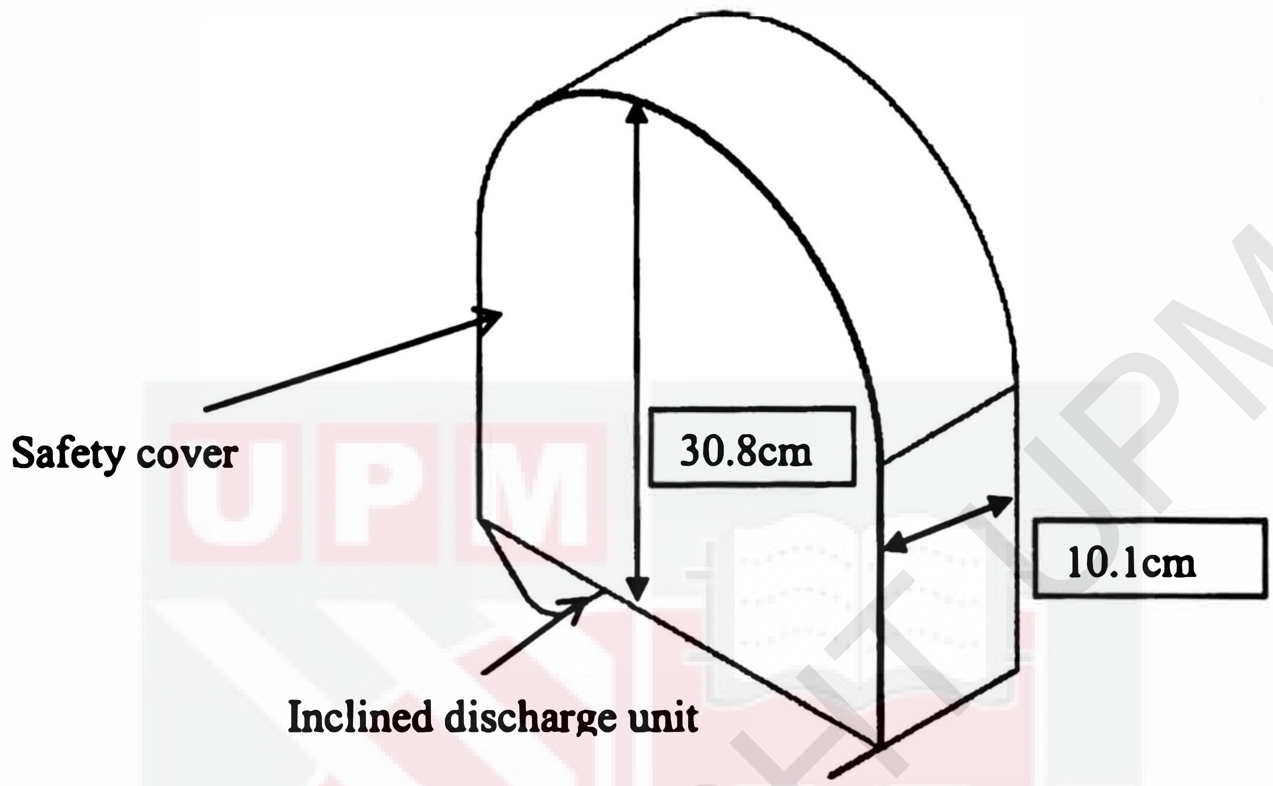


Figure 3.21 Schematic view of cutting chamber

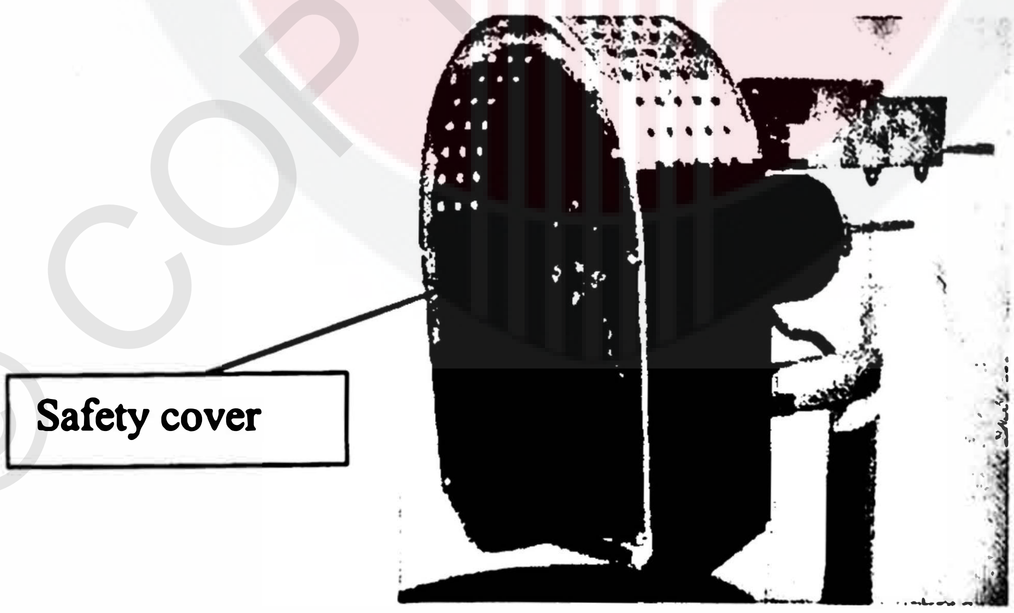


Figure 3.22 Real view of cutting chamber

3.3.3.2 Three-blades rotary cutting disc

In this machine, rotary cutting disc is used which comprised of three blades as shown in Figure 3.25 that function to slice the banana into slices. The cutting disc is located in the cutting chamber which rotates in counter clockwise at 360° due to the 40 W powers transmitted from the electric motor connected via shaft and coupling. The rotary cutting disc which made from mild steel has diameter of 270 mm and weight of 1.26 kg that can be detached for cleaning purpose.

Each of the blades attached on the rotary cutting disc having exemplary width of 10 mm and 105 mm in length with 30° inclined bevel along both right and left edges of the blade as illustrated in Figure 3.25. The blades also consist of two holes located at both end of the blades which the diameter is 4.5 mm respectively. For hygienic purpose, the blades that loaded by the screw at apertures of both ends of the blades could be detached to clean the blades after used. This is to keep the blades cleaned and prevent from rusting for prolong the time usage of the machine. Other than that, the blades also could be replaced by appropriate blades for purpose of different thickness slicing and shredding..

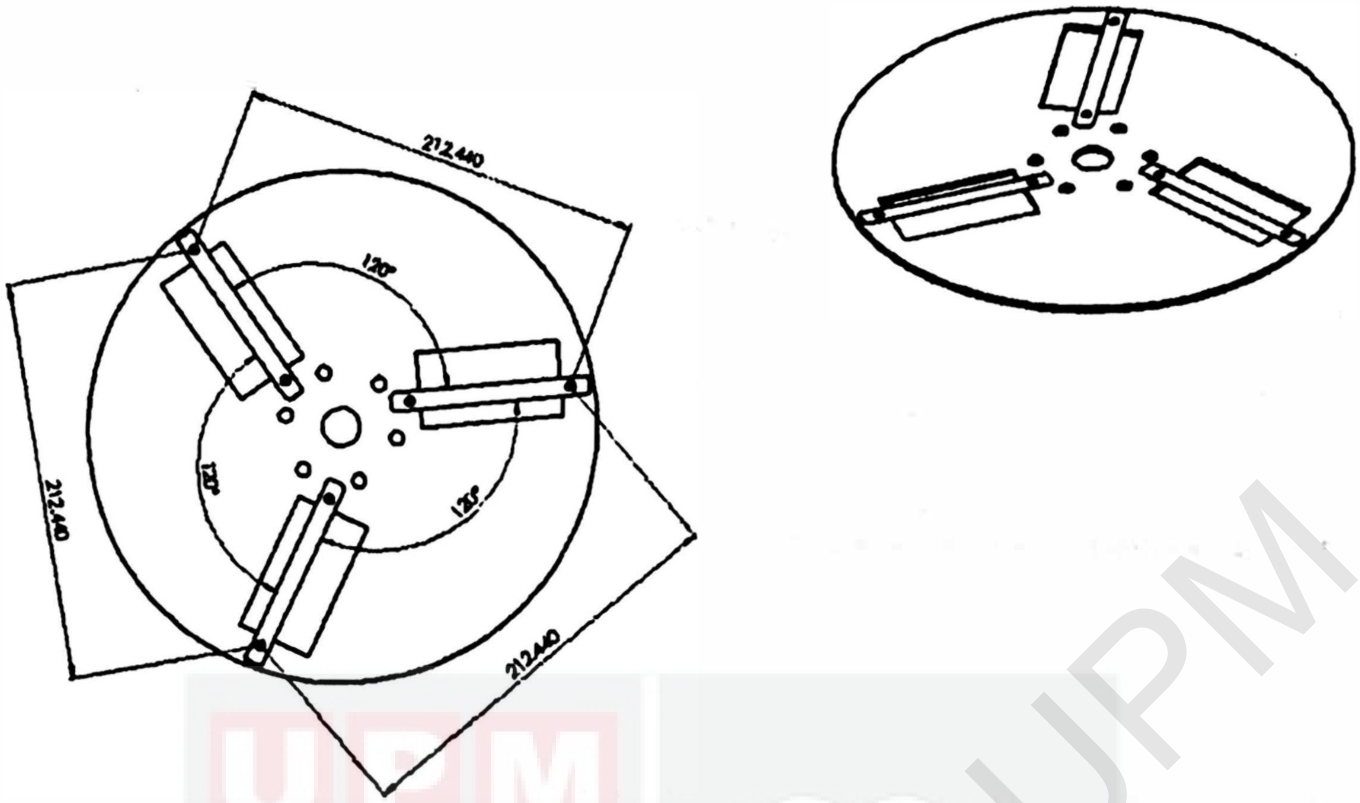


Figure 3.23 The schematic diagram of 3-blades rotary cutting disc

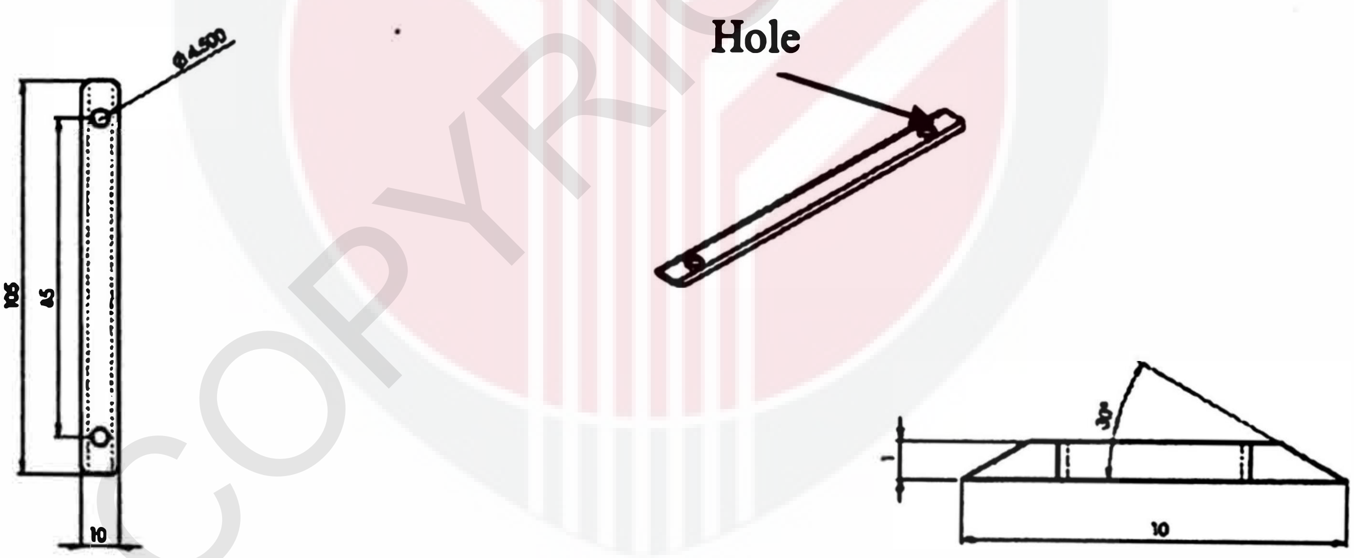


Figure 3.24 The schematic diagram of the blade

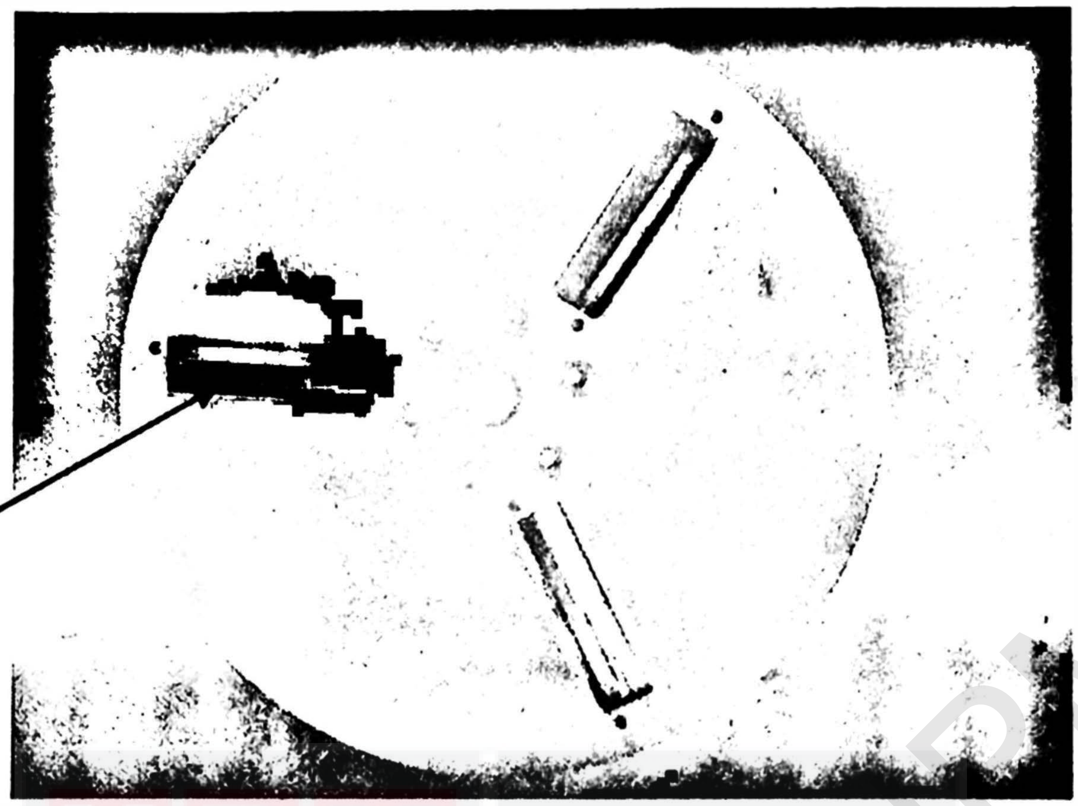


Figure 3.25 The real view of 3-blades rotary cutting disc

3.4 Parameters in Designing Machine

3.4.1 Determination size of banana

Some of physical properties of banana fruit are important in designing the main component of the machine. The parameters that need to be giving emphasize in this machine is the size (length and diameter) of the fruit.

Raw banana for tests were purchased from a wholesale market in Seri Kembangan, Selangor. In this project, *Pisang Abu* and *Pisang Nangka* were selected as varieties of banana that used as feedstock of the machine. This is because they were mostly used in production of banana chips and mostly available in market. For that reason, the length and diameter of the banana fruit need to be measured to obtain the average, maximum and minimum size of the fruit. This parameter is important to design size of the feeders use for banana loading.

20 tubers of banana were selected randomly and peeled to be measured using A pair of vernier calipers, a thread which has length of 30 cm and a ruler. The data obtained is tabulated in Appendix E. The measurement of length and diameter is taken using based on the Figure 3.26, 3.27 and 3.28 below.

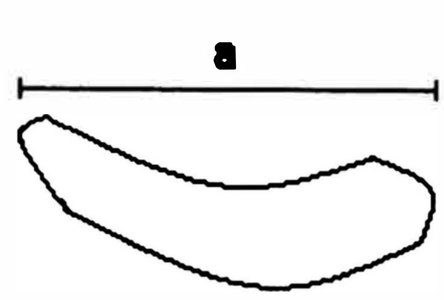


Figure 3.26 Measurement of Length$_a$ of the banana

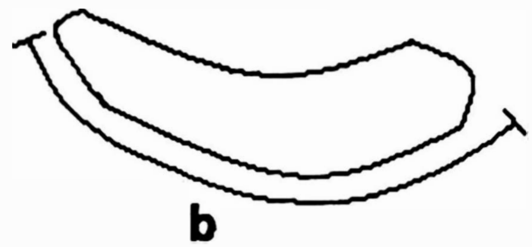


Figure 3.27 Measurement of Length$_b$ of the banana

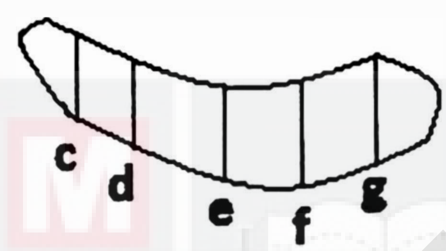


Figure 3.28 Measurement of diameter is taken based on the mean of the cross-section of banana

3.5 Performance test of the machine

Performance test is done to detect the weakness of the machine for improvement based on the production capacity and other related parameters.

3.5.1 Determination of production capacity of banana

Before the performance test is done, the machine has been assembled completely. The cutting disc is connected to the shaft and electric motor. A deep-fryer was placed below the chute of discharge unit and edible oil was applied onto the blades to reduce the potential adhesive effect due to the adherent properties of the banana. Thus, the efficiency of the slicer machine would be improved.

The orientation of banana into the feeders will affect the production capacity. Therefore, performance test on banana is run at these categories:

- Vertically subjected to the circular feeder
- Horizontally subjected to the longitudinal feeder
- Vertically subjected to the longitudinal feeder

The samples of the banana are selected randomly and five experimental replications were carried out with time recorded using stopwatch. Average production at each categories mentioned above is calculated. . The production capacity can be determined using equation 3.1 below.

$$Production\ capacity = \frac{Weight\ of\ food\ solid\ (kg)}{Time\ taken\ to\ slice\ food\ solid (hr)}$$ **Equation 3.1**

3.5.2 Determination of production capacity of multi-food solid

Production rate of other food solid such as cassave, sweet potato and carrot also being tested using same method as in sub-topic 3.5.2 to achieve the objective of this project as mentioned in Chapter 1. However, the food solid need to be cut first into the size that fit the feeder and the performance test on multi-food solid is run at two categories which are:

- Vertically subjected to the circular feeder
- Horizontally subjected to the longitudinal feeder

The production capacity of multi-food solid can be determined using equation 3.1 at sub-topic 3.5.1. The data were tabulated and calculated.

3.5.3 Determination of average thickness of sliced banana

The determination on thickness of sliced banana is very important to determined the performance of the machine. According to Faizul (2016), the best crispness of banana chips can be enjoy with thickness ranging between 1.0mm to 1.2 mm of sliced banana.

1 kg of peeled bananas were taken to be sliced using circular and longitudinal feeder . 30 pieces of sliced banana were taken to be measured their thickness by using a pair of vernier callipers. The data is tabulated and calculated. The judgement of the selecting the sliced banana to be measured is considering the bananas were sliced completely into thin layer and retain thelongitudinal shape

3.5.4 Determination of appropriate time required for frying

Faizul (2016) reported that the slices banana need to be fried in edible oil until yellowish color is formed to be taken out from the fryer. An appropriate time taken for the banana slices to be fried in the process is important to indicate that the fried banana was cooked and can be eat.

The fryer was filled with one liter of edible oil and set into deep-frying mode by adjusted the temperature controller. The edible oil was heated in the fryer until temperature of 180°C was achieved. The temperature of the edible oil was checked using a HOBO data looger. Four trial had be done where 264g of banana was set to be fried in the deep-fryer by 4 minutes, 5 minutes, 4.5 minutes and 4.5 minutes accordingly. The changes on the color of the banana during frying is observed and discussed. The temperature of the edible oil was checked regularly to be at 180°C.

3.5.5 Determination of available weight for one batch of frying

Frying mechanism is one of the main component of this machine. The machine is designed to be used direct for frying using a deep-fryer. The deep-fryer used in this machine is Pensonic Multi-cooker which can be found in the market. An experiment was done to determine the available weight of one batch banana can be cook in the 3.8L of the fryer.

The fryer was filled with one liter of edible oil and set into deep-frying mode by adjusted the temperature controller. The edible oil was heated in the fryer until temperature of 180°C was achieved. The temperature of the edible oil was checked using a HOBO data looger. Four trial had be done where weight of banana slices at 360g, 300g, 264g and 264g was set to be fried with 1L of edible oil in a deep-fryer for 4.5 minutes. The changes on the appearance of the banana was observed. The temperature of the edible oil was checked regularly to be at 180°C . Assumed that maximum volume of edible oil could be filled in the deep-fryer is 3L. Therefore, the weight available for one batch of frying was calculated using equation 3.2 below.

Available weight of one batch frying = 3 L x weight required /1L **Equation 3.2**

3.5.6 Determination of operating cost

Operating cost is important to be calculated to estimate the break-event point. In calculating operating cost of one batch production of longitudinal banana slices, electricity was not considered. Only labor cost needed to compare the operating cost between using manual method and machine. The calculation on the operating cost was calculated by taking into account of these assumptions which were:

- 1 batch of processing needed to slice 100 kg of banana
- Total cost labor per hour was RM7/hr. labor
- Electricity cost was negligible
- Only one operator needed to run the process for both method

The equation used in determine the operating cost using banana slicer machine and the manual method are shown below.

$$Operating\ cost\ (RM) = 100kg \times \frac{1}{capacity\ production} \times \frac{RM7}{hr.labour} \times 1\ labour$$

Equation 3.3

From data obtained above, ratio of operating cost of manual method to the banana slicer machine was determined as below equation.

$$Ratio = \frac{Operating\ cost\ of\ manual\ method}{Operating\ cost\ of\ banana\ slicer\ machine}$$ **Equation 3.4**

3.5.7 Prototype analysis

The fabricated prototype was tested, evaluated and analyzed to identify problem and weaknesses. The problem identified and the solution of the problem is tabulated in Table 3.8.

Table 3.8 Problem identified and the solution

No.	Problem	Solution
1	Unable to slice efficiently when more than one tuber of solid is load into the longitudinal feeder. The food solid may overlap when being drive into the cutting disc and caused ununiformed thickness of food solid slices.	Design adjustable cover plate on the longitudinal feeder to ensure the food solid is hold accordingly in position there by, the uniform thickness of sliced food product could be achieved.
2	Hard to remove the safety cover of the cutting chamber when need to remove food solid that stacked at the blades.	Attach hinges at the side of the cutting chamber with locker at the opposite side foe easily detach

3.6 Design modification and improvement

Based on the prototype analysis the problem and weaknesses of the machine is identified. The weakness of the machine is detected at the longitudinal feeder where the food solid may overlap when more than one tuber were loaded into the feeder. Thus, an adjustable cover plate is designed on the longitudinal feeder to overcome this problem. The plate is made from stainless steel which attached to the longitudinal feeder by of two screws each at both left and right sides of the feeder. The screws could be loose to move up or down the plate on the food solid depend on their size. The cover plate is locked again by tighten the screw in order to ensure the food product is accordingly in position thereby, the uniform thickness of sliced food product could be achieve. Therein some holes on the adjustable cover to define the food products could be removed or adjusted if get caught in the feeder during cutting process.

Meanwhile at cutting chamber, the safety cover is hard to remove due to many steps that take time. If there is foods solid stacked at the blade, it is necessary to open the safety cover to remove them to prevent from disturbing the production. To overcome this problem, hinges are attached at the side of the cutting chamber with locker at the opposite side for easily detach.

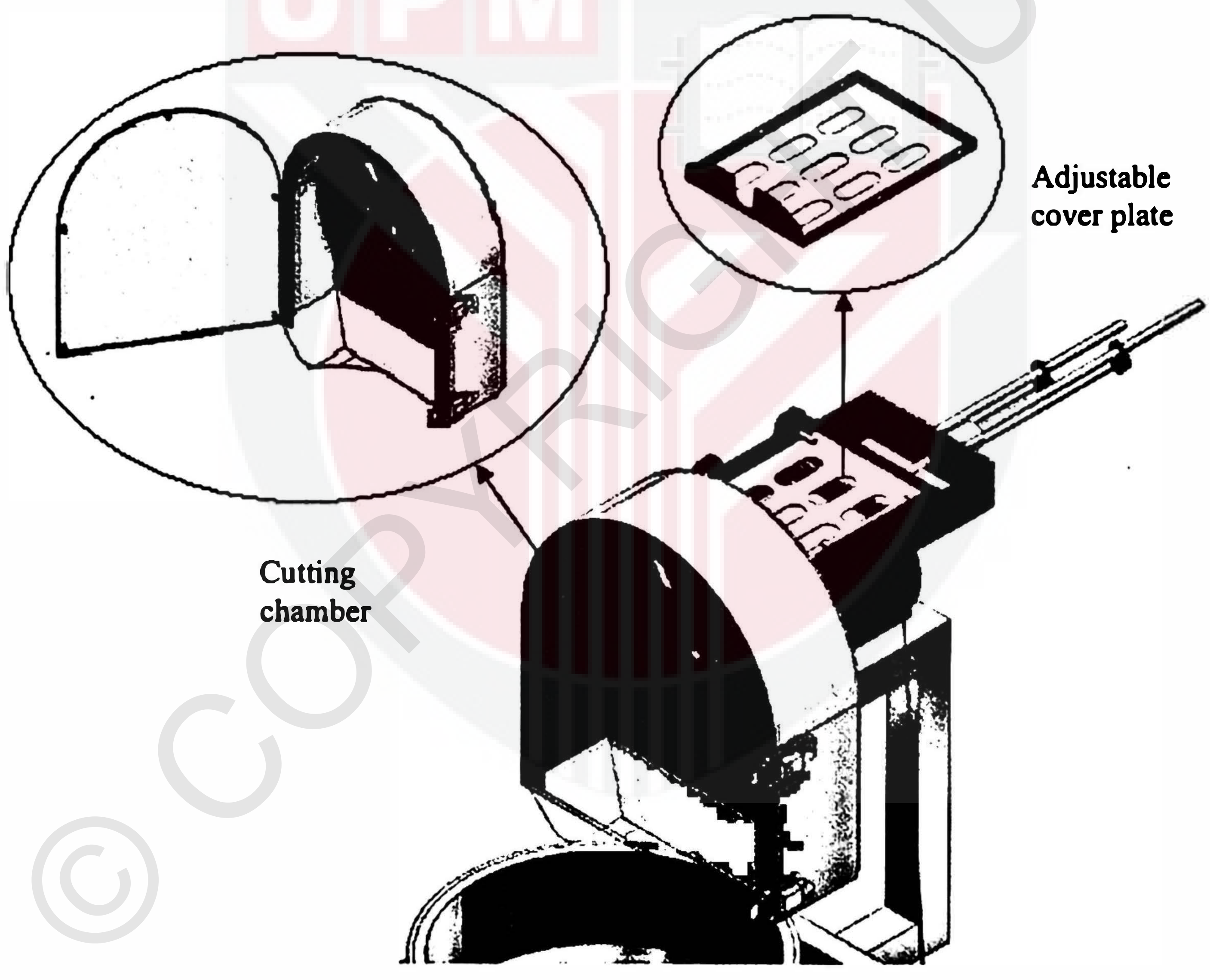


Figure 3.29 New improvement of the machine

3.7 Safety consideration

During design and fabrication of Banana Slicer Machine, the most important thing needed to be considered is safety. Safety is very important to ensure unwanted accident or any injuries occur. Listed below are the factors that have been considered:

a) Any sharp and potentially cause hazard parts or components are fully covered.

   Example: 3-blades rotary cutting disc and motor

b) The surface that has direct contact with the food products are made from stainless steel and food grade materials.

   Example: longitudinal feeder, circular feeder, pushers, 3-blades rotary cutting disc, adjustable cover and cutting chamber.

c) The safety cover of the cutting chamber is made from Perspex which is available to resist heat temperature from the deep-fryer

For cleaning and maintenance purpose, cutting mechanism is design in easily assemble and dissemble way.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Machine design

Figure 4.1 below shows the banana slicer machine. The dimension of the machine is 970 mm (length) x 500 mm (width) x 1240mm (height). The cutting mechanism of the machine is controlled by electric motor with 40W.

Figure 4.1 Banana Slicer Machine

Banana slicer machine is a semi-automatic which needs an operator or user to load the banana into the feeder manually. Feeder is where banana is amounted in the machine to be conveyed to the cutting disc to be sliced. The orientation of the feeder is designed to be perpendicular to the cutting disc to give priority in producing longitudinal banana slices. This orientation will reduce the potential of the banana to overlap during the process and increase the ability to get uniform thickness of the banana slices. Longitudinal banana slices can be produce when subjecting banana horizontally in the feeder to the cutting disc while circular banana slices can be produce by subjecting vertically. The specialty of these feeders in this machine is the feeder is connected with load system which means the man power could be reduce during the slicing process. The load system is functioned as driven force to the pusher to move the banana towards cutting disc by gravitational force. Other than that, longitudinal feeder of this machine can produce longitudinal and circular banana slices by subjecting the banana horizontally and vertically.

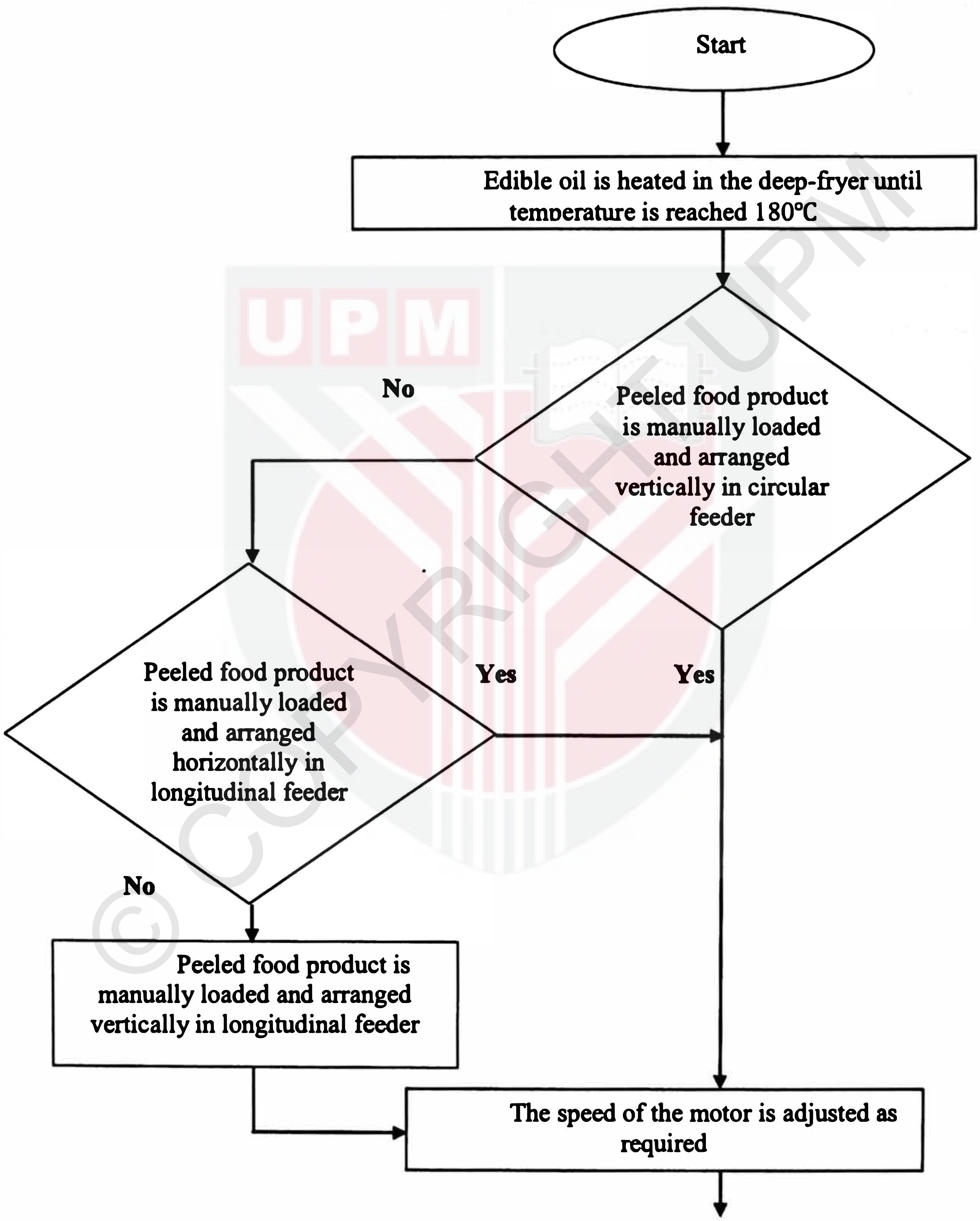
The present invention is accomplished with the adjustable cover plate that amounted on the longitudinal feeder. As a result of much experimenting, the adjustable cover is placed on the longitudinal feeder to prevent the food product to overlap during the slicing process. The adjustable cover plate comprises of two screws each at both left and right sides of the feeder. The screws could be loose to move up or down the plate on the food products depend on their size. The cover plate is locked again by tighten the screw in order to ensure the food product is accordingly in position thereby, the uniform thickness of sliced food product could be achieve. Therein some holes on the adjustable cover to define the food products could be removed or adjusted if get caught in the feeder during cutting process.

In slicing process, three-blade rotary cutting disc is used to cut the banana where all the three blades able to cut the banana that pass through, thus enhance the rate of production. In this process, cutting chamber is functioned to reduce mess of output banana produce due to the force exerts during slicing process. The slices of banana are eventually fall in the deep-fryer through the discharged unit at the end of the cutting chamber. Table 4.1 shows the summary of all parts in banana slicer machine.

Table 4.1 Summary of all parts in banana slicer machine

Parts or components	Description
Safety Cover	To prevent the exposure towards cutting disc
Cutting Chamber	To cover the rotary cutting disc
3-Blades Rotary Cutting Disc	To cut the banana into slices
Longitudinal Feeder	To feed the banana to the rotary cutting disc for producing banana in longitudinal and circular shape
Circular Feeder	To feed the banana to the rotary cutting disc for producing banana in circular shape
Induction Motor	To supply mechanical energy
Speed Controller	To control the speed of the rotary cutting disc
String	To connect the pusher with the load
Load	To move the feeder towards the rotary cutting disc
Skeleton	To connect the cutting chamber with working cabinet
Working Cabinet	To store the rotary cutting disc, deep-fryer after used and other tools
Caster Wheel	To move the machine
Load housing	To give pathway to the load
Adjustable cover plate	To control the thickness of the banana in the longitudinal feeder
Deep-fryer	To fry the banana for making banana chips

4.2 Machine operation



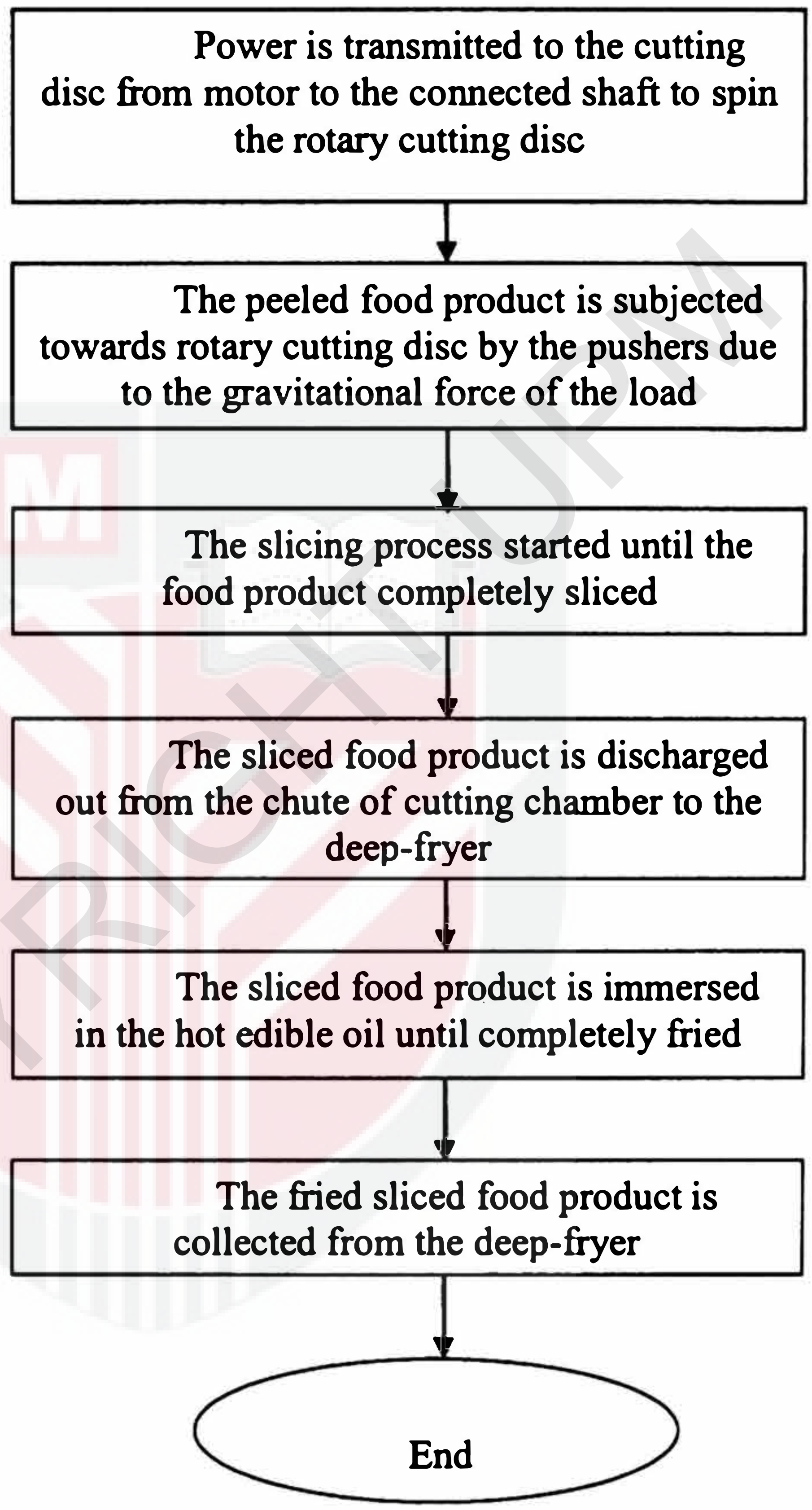


Figure 4.2 Flowchart of the machine operation

Based on the Figure 4.2 above, the process of slicing can be run by using one feeder at one time either circular feeder or longitudinal feeder. In longitudinal feeder, the peeled banana could be arranged in vertical or horizontal order. The operation of the present invention started with the heating of edible oil in frying pan until 180°C. Before peeled banana is loaded in the feeder, the pusher that comprised of push lid and push plate that placed in the feeder are need to be drawn out by operator to the end of the feeder. As the pusher is drawn out, the string that attached to the pusher will pull the load to the top of the housing. An operator needs to hold the pusher by hand until bananas are loaded completely in the feeder so that the peeled banana could be arranged in the space of feeder. Averagely, the feeder is able to hold up to eight numbers of tubers of banana for longitudinal feeder and three for circular feeder to be sliced at one time depends on the size of the banana. After finish loading the banana in the feeder, an operator can hands-off from pusher. At this condition, the bananas are in ready state to be slice. In addition, if longitudinal feeder is used, the adjustable cover plate on the feeder could be adjusted by loosen the screws at both side of the feeder and move the screws up and down to get the best position. After the position is fixed, the screws are tighten back. Averagely, the feeder is able to hold up to eight number of tubers of banana for longitudinal feeder and three for circular feeder to be sliced at one time depends on the size of the banana.

The speed of the motor can be adjusted from 90 to 1700 rpm depends on the requirement of the process or operator using the speed controller at located at left side of working cabinet. As the switch is on, 40W power of electric motor will drive the rotary cutting disc in counter-clockwise through shaft to cut the bananas. The bananas will move forward to the cutting disc due to force driven by gravitational force of the load. The load that at first been pulled to the top of the housing of the load will move downward due to the gravitational force, then it caused the pusher to move forward horizontally to the cutting device. The slicing process automatically continues until the banana completely sliced. The sliced banana is discharged out from the discharge unit of cutting chamber to the deep-fryer and immersed in the edible hot oil until completely fried. Lastly, the fried banana chips are collected from the deep-fryer.

4.3 Bill of material (BOM)

A bill of materials (BOM) relates to list of parts, items, assemblies and sub-assemblies required to define a finish product (BOM Management, 2017). The bill of materials can be understood as the recipe and shopping list for creating a final product. It is important to create an accurate bill of material, especially for a new product, as it is vital for the correct parts to be available when the item is being manufactured. Some problems could be occurred if the bill of materials is not correct which caused delay in fabrication and may lead the production to be stop (Murray, 2016). Figure 4.3 is an exploded view drawing showing the relationship and order of assembly of various parts.

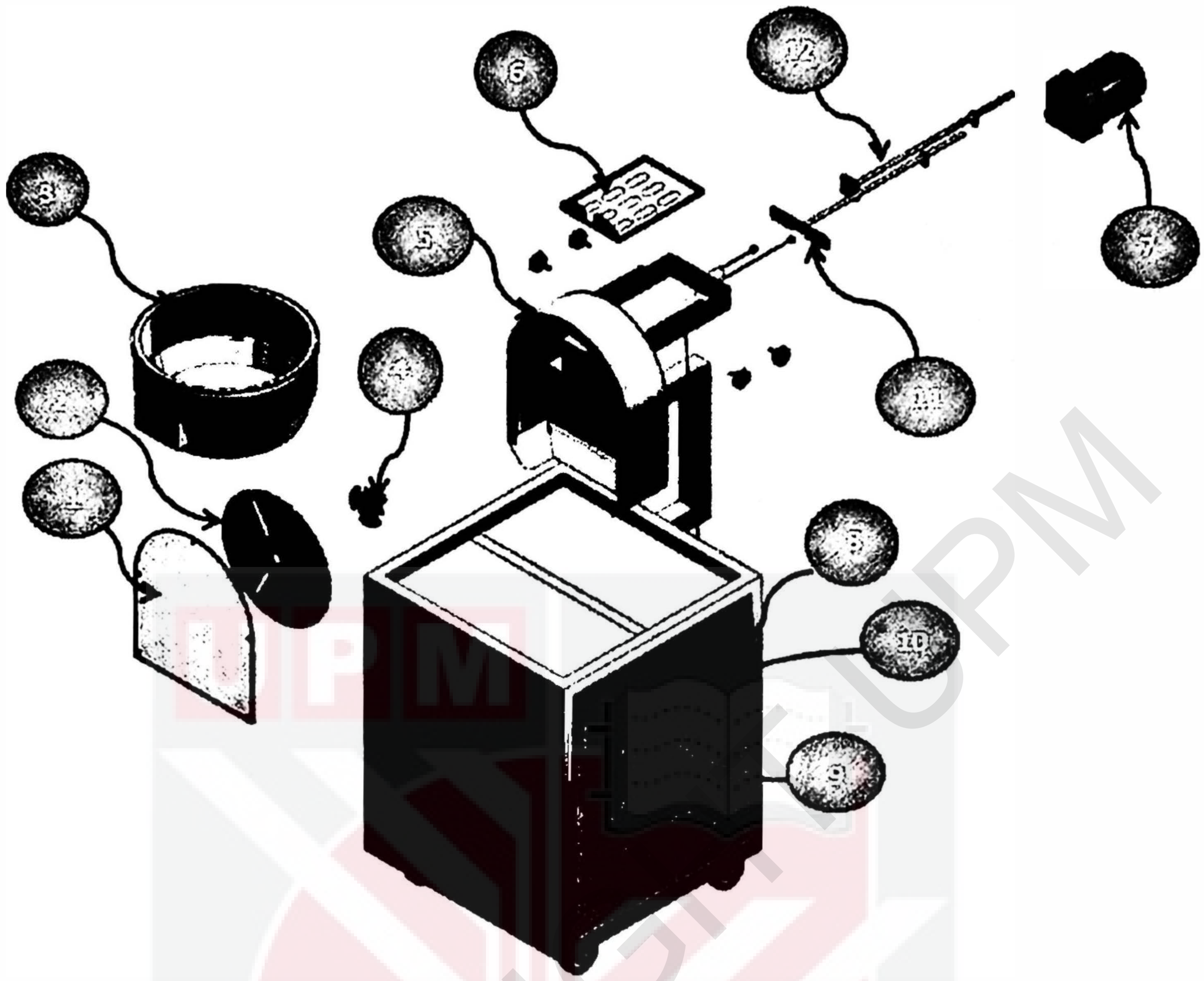


Figure 4.3 Exploded view of the machine

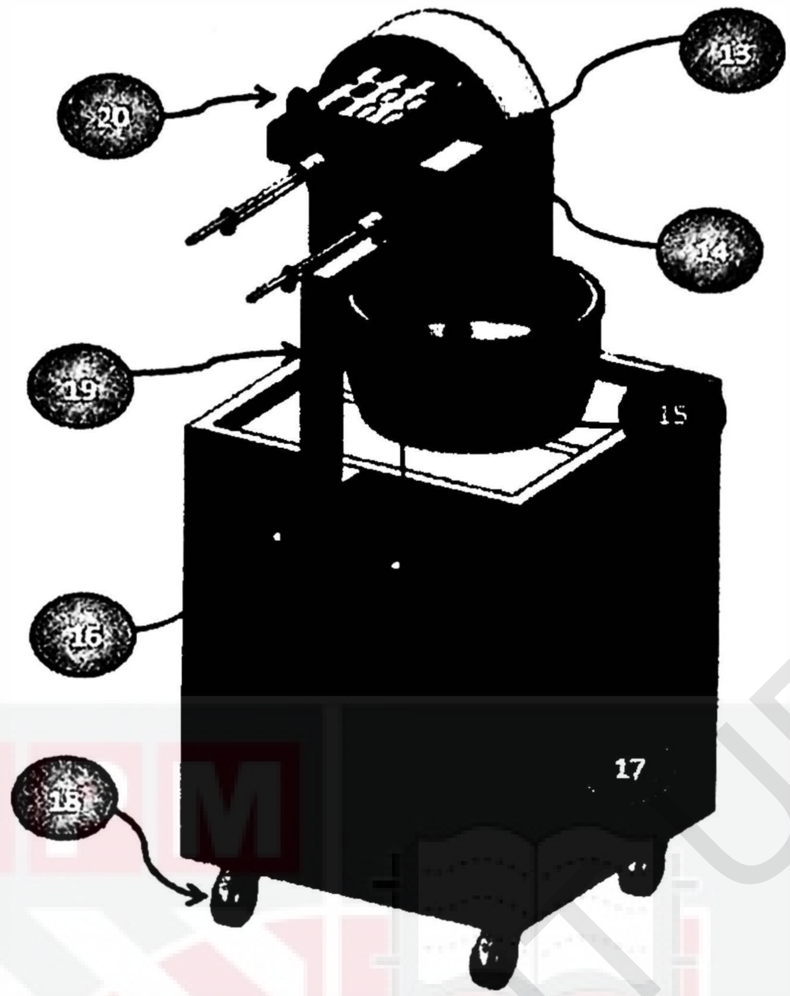


Figure 4.4 View back of the machine

Item No	Description	Quantity
1	Safety Cover	1
2	3-Blades Rotary Cutting Disc	1
3	Deep-Fryer	1
4	Coupling	1
5	Cutting Chamber	1
6	Adjustable Cover Plate	1
7	Electric Motor	1
8	Working cabinet	1
9	Switch	1
10	Speed Controller	1
11	Push Plate	1
12	Push Lid	1
13	Longitudinal Feeder	1
14	Circular Feeder	1
15	String	2
16	Load	2
17	Housing	2
18	Caster Wheel	4
19	Skeleton	1
20	Screw of the Adjustable Cover	4

4.4 Size of banana

20 tubers of banana were selected randomly and peeled to be measured using a pair of vernier calipers, a thread which has length of 30 cm and a ruler. The data obtained is tabulated in Appendix F. Table 4.2 below shows the summary of averages of physical properties of banana

Table 4.2 Summary of averages of physical properties of banana

Parameters	Min	Max	Mean	Std
$Length_a$ (mm)	95	192	135.2	36
$Length_b$ (mm)	103	149	169	18
Diameter (mm)	33	42	26	3
Weight (g)	52	85	25	20

The results shows that the average $length_a$ of the banana is 135.2mm and the diameter is 36 with the standard deviation of 36and 3 respectively. Therefore, the size of the feeder is set to be 170 mm (length) and 42mm (width).

4.5 Performance analysis

4.5.1 Production capacity of banana

The production capacity of the banana slicer machine was measured in term of weight of the banana slices produced in one hour. In this test, production capacity is calculated at three categories that mentioned in sub-topic 3.5.1. The time to completely slice the banana is recorded and the test was repeated five times and average production capacity was calculated using Equation 1. The production rate of sliced banana were done by using the optimum speed of 1700 rpm and a load used to move each circular and longitudinal feeder was 1kg. The data obtained is calculated and tabulated in Appendix F and Table 4.3 below shows the summary of average production capacity of banana.

Table 4.3 Summary of average production capacity of banana

Type of feeder	Longitudinal		Circular
Orientation of the feeder	Horizontally	Vertically	Vertically
Rate (g/s)	3.4	7.2	4.7
Rate (kg/hr)	12.2	25.92	16.9

The capacity obtained when banana is subjected horizontally in longitudinal feeder is 12.2 kg/hr. The results of capacity of banana subjected vertically in longitudinal feeder and circular feeder is need to be compared to determine the most efficient method in producing circular banana chips of this machine.

Based on the results obtained above, the capacity of banana subjected vertically in longitudinal feeder has capacity of 25.92 kg/hr while 16.9 kg/hr in circular feeder. As expected, longitudinal feeder can slice more efficient in vertical oriented than circular feeder by 9% due to more bananas can be amounted in the longitudinal feeder compared to circular feeder.

4.5.2 Production capacity of multi-food solid

Instead of producing sliced banana to make banana chips, the slicer machine also is determine to slice multi-food products such as cassava, sweet potato and carrot by using this machine. Performance test on these multi-food solid is made to determine their production capacity. The data obtained is calculated at two categories that mentioned in sub-topic 3.5.2 and tabulated in Appendix F and the summary average production capacity of multi-food solid is shown in Table 4.4 below.

Table 4.4 Summary average production capacity of multi-food solid

Types of food products	Production capacity Circular feeder (Vertically)		Longitudinal feeder (Horizontally)	
	Rate (g/s)	Rate(kg/hr)	Rate (g/s)	Rate (kg/hr)
Banana	4.7	16.9	3.4	12.20
Cassava	4.0	14.4	3.6	12.96
Sweet potato	4.6	16.6	4.6	16.56
Carrot	3.7	13.3	8.8	31.68

From the Table 4.4 above, we can conclude that all multi-food solid above are able to be sliced using this machine. Indeed the production capacity of these food solid are much better than banana fruit. This is because of banana is less dense than them (cassava and carrot). Based on the Appendix F, the density of cassava , sweet potato and carrot are 0.63 g/ml, 0.44g/ml and 0.64 g/ml respectively, while density of banana is 0.46g/ml based on data obtained in determine size of banana. Therefore, we can conclude that the less dense of food solid has lower production capacity during slicing compared to denser foods solid.

4.5.3 The average of thickness of the banana slices

For 1 kg of sliced banana using circular feeder and longitudinal feeder , a few samples had been taken to measure their thickness. A pair of vernier caliper was used to determined the thickness. From the data tabulated in Appendix F, the mean thickness obtained for circular and longitudinal shape were 1.0 mm and 1.1 mm respectively. The ideal thickness sliced banana for making banana chips was 1.0- 1.2 mm (Faizul, 2016). From this, the thickness produced by the new invention machine has meet the requirement needed by the industy.

4.5.4 Time and temperature required for frying banana chips

Trial and error method is used to determine the time and temperature for frying the banana with edible oil at 180°C. Sliced banana were fried for different periods to get yellowish color at 180°C. Based on the table below, required time of 4.5 minutes was acceptable.

Table 4.5 The time and temperature for frying banana chips

Oil temperature, °C	Time required,min	Color
180	4.0	Pale yellowish
180	5.0	Dark spot
180	4.5	Yellowish
180	4.0	Yellowish

In this experiment, temperature of oil is set as constant variable and time required for frying the banana slices is set as manipulated variable to obtained the appropriate time to fry banana slices. The appearance color of the banana slices is important to indicate that they are fried and could be take out from the fryer. Based on the results, for the first trial the obervation on the color of banana is pale yellow for 4 minutes. As the results of appearance obtained is not as expected, the time for frying is continue for 1 minute but as the results the fried banana is overcooked and dark spot is observed. After that, time for frying is set to be 4.5 minutes and yellowish color of the fried banana chip is obtained. The test was run for a second time to get the accurate results and the color obtained is yellowish. Therefore, we can conclude that the appropriate time required for frying 264 g of banana slices in the deep-fryer is 4.5 minutes at temperature of 180°C edible oil.

4.5.5 Availabe weight for one batch frying

Trial and error method is used to determine the suitable weight for one batch frying in 3.8 L of deep-fryer. Sliced banana with different amount were fried in 1L of edible oil to get desired appearance without agglomeration. In the table below shown the observation that had been taken.

Table 4.6 Available weight for frying in 1L of edible oil

Oil temperature, °C	Volume of oil,L	Time,min	Weight required, g	Observation
180	1	4.5	360	Agglomirate
180	1	4.5	300	Agglomirate
180	1	4.5	264	No agglomirate
180	1	4.5	264	No agglomirate

From the table above, the available weight for frying the banana chips was 264g in 1L of edible oil. Thus, the available weight to fry the sliced banana in 3.8 L of deep fryer was 1003.2 g which approximately 1kg.

4.6 Engineering Economic Analysis

During solving the problems of an invention, economic viability of each potential is taken into account along the technical aspect. Besides that, an invention should be able to targeted customer and the price of the invention should also worth investment and value for money.

4.6.1 Cost Estimation of Machine

The invention is built to gain profit. Therefore, the one-time investment required for the machine is estimated as Table 4.8.

Table 4.7 Cost estimation

Item	Amount (RM)
Hollow steel, steel plate, round bar steel, bolt, nut, shaft	1500
Caster wheel, nylon string	100
Perspex acrylic sheet	50
Blades	20
Electrical & Wiring	70
Machining & Fabrication	550
Electric motor	1500
Total	**RM3790**

4.6.2 Operating Cost

Operating cost of banana slices machine and manual method were calculated using equation 3.3 in sub-topic 3.5.6. as shown as below

By using manual method;

$$Operating\ cost\ (RM) = 100kg \times \frac{1}{1.62kg/hr} \times \frac{RM7}{hr.labour} \times 1\ labour = RM432$$

By using banana slicer machine;

$$Operating\ cost\ (RM) = 100kg \times \frac{1}{\frac{12.2kg}{hr}} \times \frac{RM7}{hr.labour} \times 1\ labour = RM57$$

For 100 kg of bananas are sliced using manual method per hour with one worker, the operating cost obtain is RM432. Meanwhile, the operating cost for 100 kg of banana need to be slice per hour with one worker is RM57. From the data obtained, the ratio of operating cost of manual method to the operating cost of banana slicer machine is calculated using equation 3.4 as shown below

$$ratio = \frac{Operating\ cost\ of\ manual\ method}{Operating\ cost\ of\ banana\ slicer\ machine} = \frac{432}{57} = 7.5 \approx 8$$

The operating cost of using banana slicer machine is 8 times lower than the operating cost of manual method using cutting board. The operation cost of producing 1 kg longitudinal banana slices can be determined which is RM 0.432 for manual method and RM0.057 by using banana slicer machine.

4.6.3 Break-even Analysis

The breakeven point (BEP) represents the sales amount, either in unit or revenue terms that required covering the total costs. Profit at BEP is zero. Beyond BEP, the customer is expected to gained profit. BEP is good to estimate how much product sold to regain the invested modal. The price of banana slicer machine is obtained from machine estimation at Table 4.8 and labor cost per kilogram product is obtain from calculation in subsection 4.5.2 Operating Cost. The estimated selling price of banana chips per kilogram is RM 8.

Price of banana slicer machine per unit	= RM3790 …….(a)
Labor cost per kg product	=RM 0.057……..(b)
Selling price of product per kg	= RM 8 ……..(c)

Based on the information, Equation 4.1 and Equation 4.2 are derived to obtain the kilogram of banana chips needed for breakeven. Fixed cost is the price of one unit of banana slicer machine. Variable cost is labor cost to produce 1 kilogram banana slices and income is the selling price of banana chips per kilogram.

Fixed cost (a) =3790

Variable cost (b) = 0.057

Income (c) = 8

Income : y =8x Equation 4.1

Cost : y = 0.057x + 3790 Equation 4.2

In Equation 4.1 and 4.2 above, x value represent the amount in kilogram of banana slices to breakeven and y represent price (RM) value of the product. To obtained the breakeven point, the interception point between the two linier equation need to be determine.

Therefore, by equating Equation 4.1 and Equation 4.2, the breakeven point can be determined by simultaneous equation.

8x = 0.057x + 3790

8.057x =3790

x = 470 kilogram

From calculation above, the estimated amount of banana chips need to be produced and sell by the entrepreneur is 470 kilograms to obtain the payback of the machine (RM3786.79). Beyond this amount, the entrepreneurs are expected to gain profit.

4.7 Advantages and disadvantages

There are some advantages and disadvantages of using the banana slicer machine compared to manual method for producing longitudinal banana slices. The summary of the comparison is shown in the Table 4.9 below.

Table 4.8 Summary of comparison between using banana slicer machine and manual method

Banana Slicer Machine	Manual method
High production rate	Low production rate
Reduce man power	Needed more man power
Less time consuming	More time consuming
Less operating cost	More operating cost
Needed more cost on fabrication	Need less cost on fabrication
Produced noise	No noise is produced

The advantage of producing longitudinal banana using banana slicer machine compared to manual method is the production rate of banana slicer machine is higher which at 12.2 kg/hr while manual method produce at 1.62 kg/hr. Besides that, by banana slicer machine the man power could be reduce due to the presence of load system compared to manual method that consumed more man power. This machine is also less time consume compared to manual method. Operating cost using the machine takes RM 57 for 100 kg of banana sliced for one hour with one worker compared to manual method the operating cost is RM432 which is 8 times greater than using the machine. Despite that, the machine also has disadvantages which is more cost are needed for

fabrication of the machine which is RM 3790 and the machine produce noise that caused by the frictional force between the blades and the motor base in cutting chamber.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

At the end of the project, a banana slicer machine that able to produce longitudinal banana chips is successfully designed and fabricated. This machine will help in reducing the man power consumed and enhance the production rate 8 times greater than manual method which the rate of production is 12.2 kg/hr. Therefore, it is highly recommended to replace the handmade manual method which is labor intensive with the banana slicer machine.

Besides that, this machine also able to test performance of other multi-food such as cassava, sweet-potato and carrot and their production capacity are 12.96 kg/hr, 16.56 kg/hr and 31.68 kg/hr respectively.

More research and development need to be conducted for further improvement since the machine is a new invention.

5.1 Recommendation

Some recommendations are suggested to be made in the future to solve the problem existed in the machinery production of banana slicer machine for producing longitudinal banana slices. Table 5.1 below shows the summary of recommendation and improvement that can be done.

Table 5.1 Recommendation of improvement that can be done

Mechanism	Recommendation
Feeding	Design adjustable feeder that can fix variety size of food products
Cutting	Improve the test performance by determine the optimum speed for the cutting disc Design 'S' shape blade of cutting disc to improve the surface area of banana that being slice, especially during slicing in longitudinal shape.

The problem arise in the feeding mechanism is the food product that has bigger dimension than the feeder need to be cut to fix the feeder designed. Therefore, an adjustable feeder is suggested to be designed so that variety size of food products could be amount in the feeder. Meanwhile in cutting mechanism, there are few improvement could be done to improve the efficiency of the machine. The test performance could be improve by determine the optimum speed for the cutting disc. Other than that, the improvement on the blade can be made by designing 'S' shape blade. This design improvement can improve the surface area of banana that being slice, especially during slicing in longitudinal shape.

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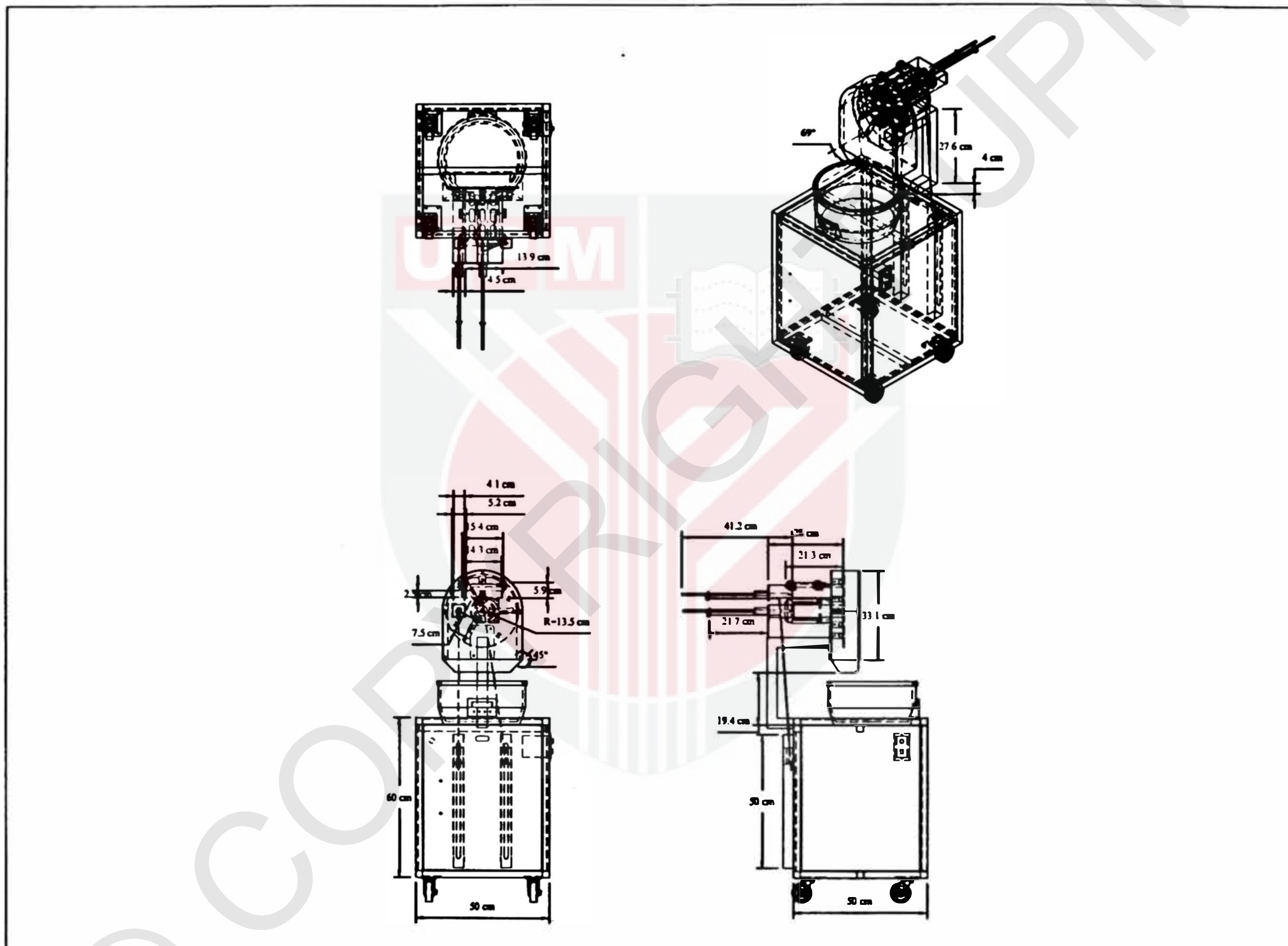
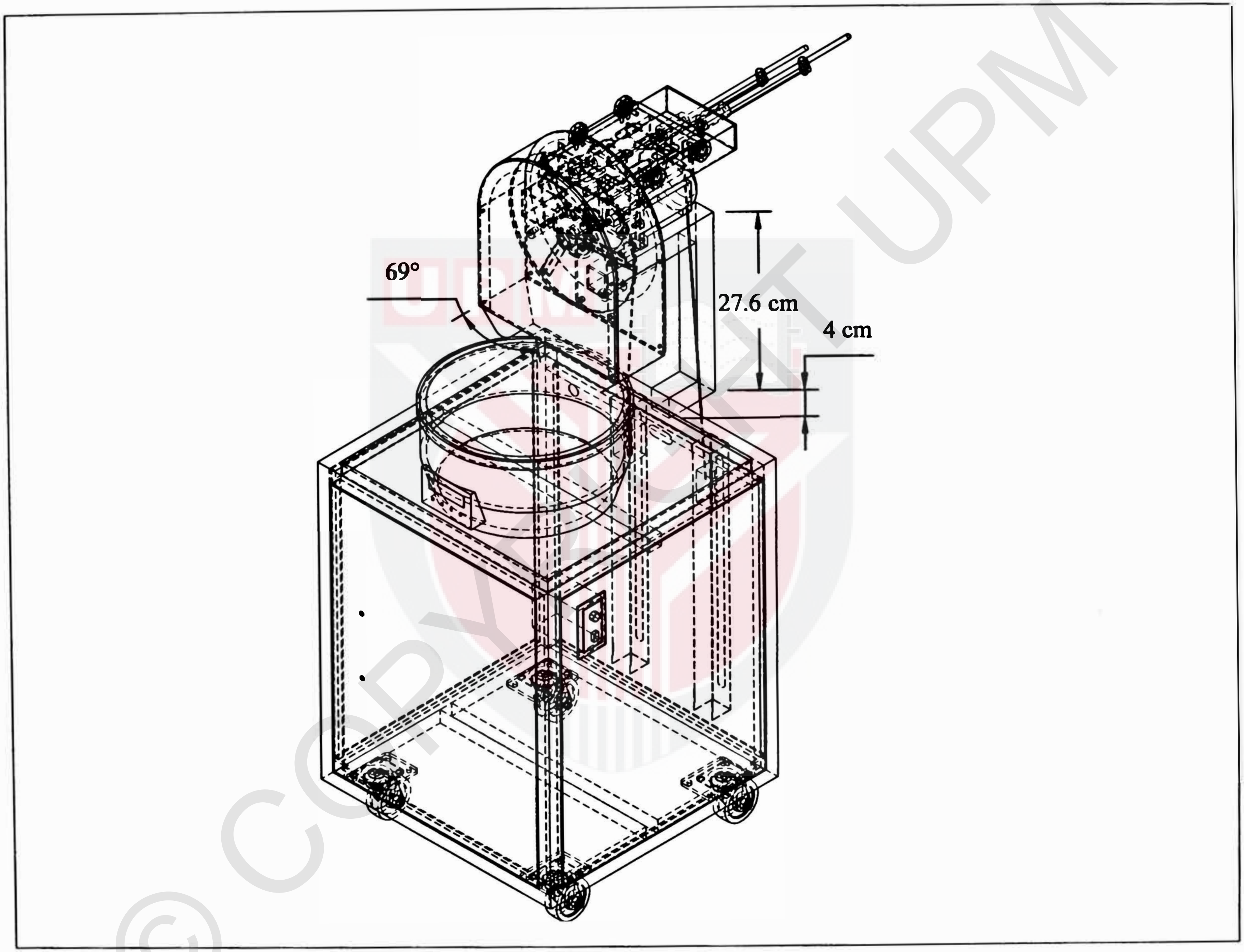
APPENDIX

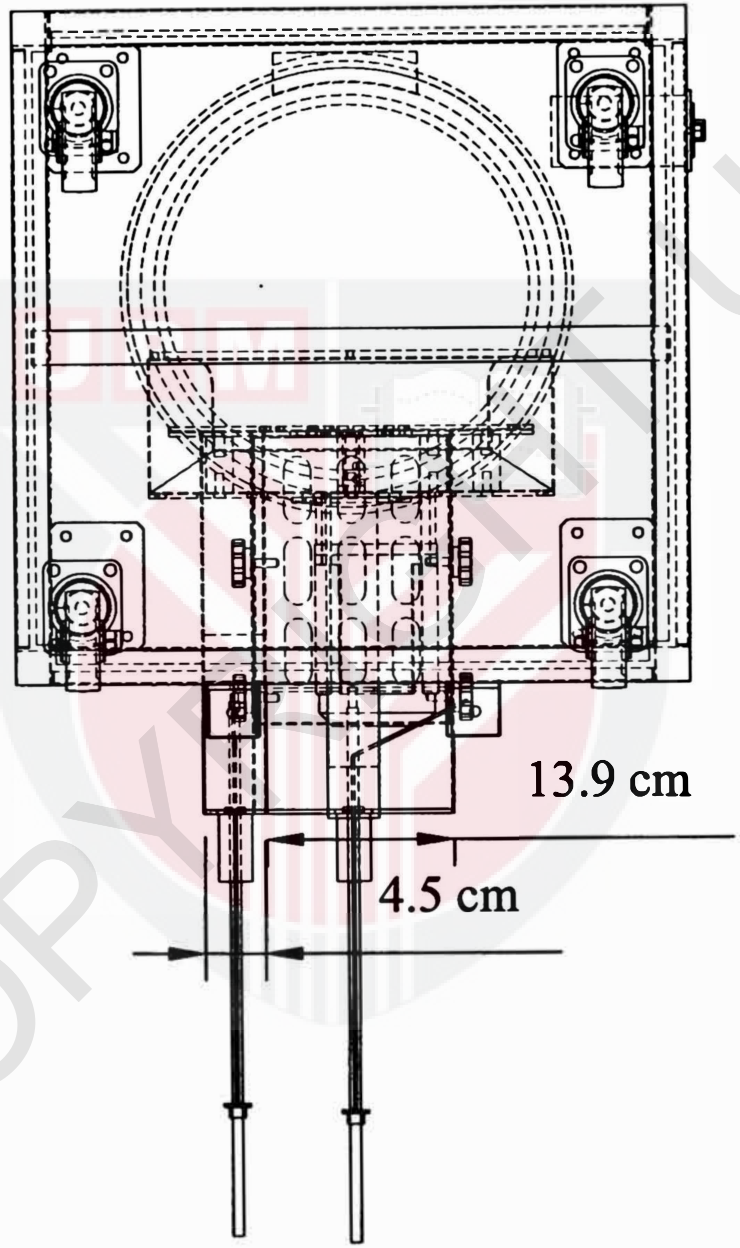
APPENDIX A



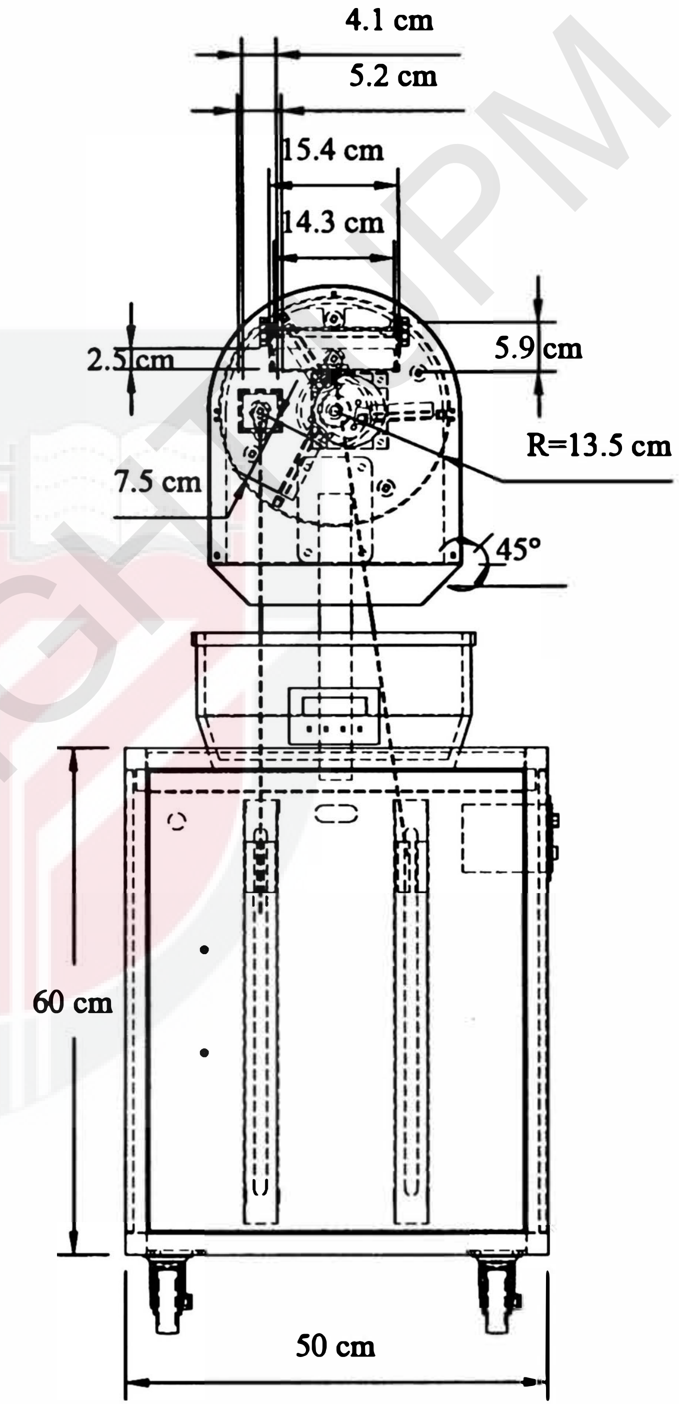
FULLY ASSEMBLE OF BANANA SLICER MACHINE



SIDE VIEW OF BANANA SLICER MACHINE

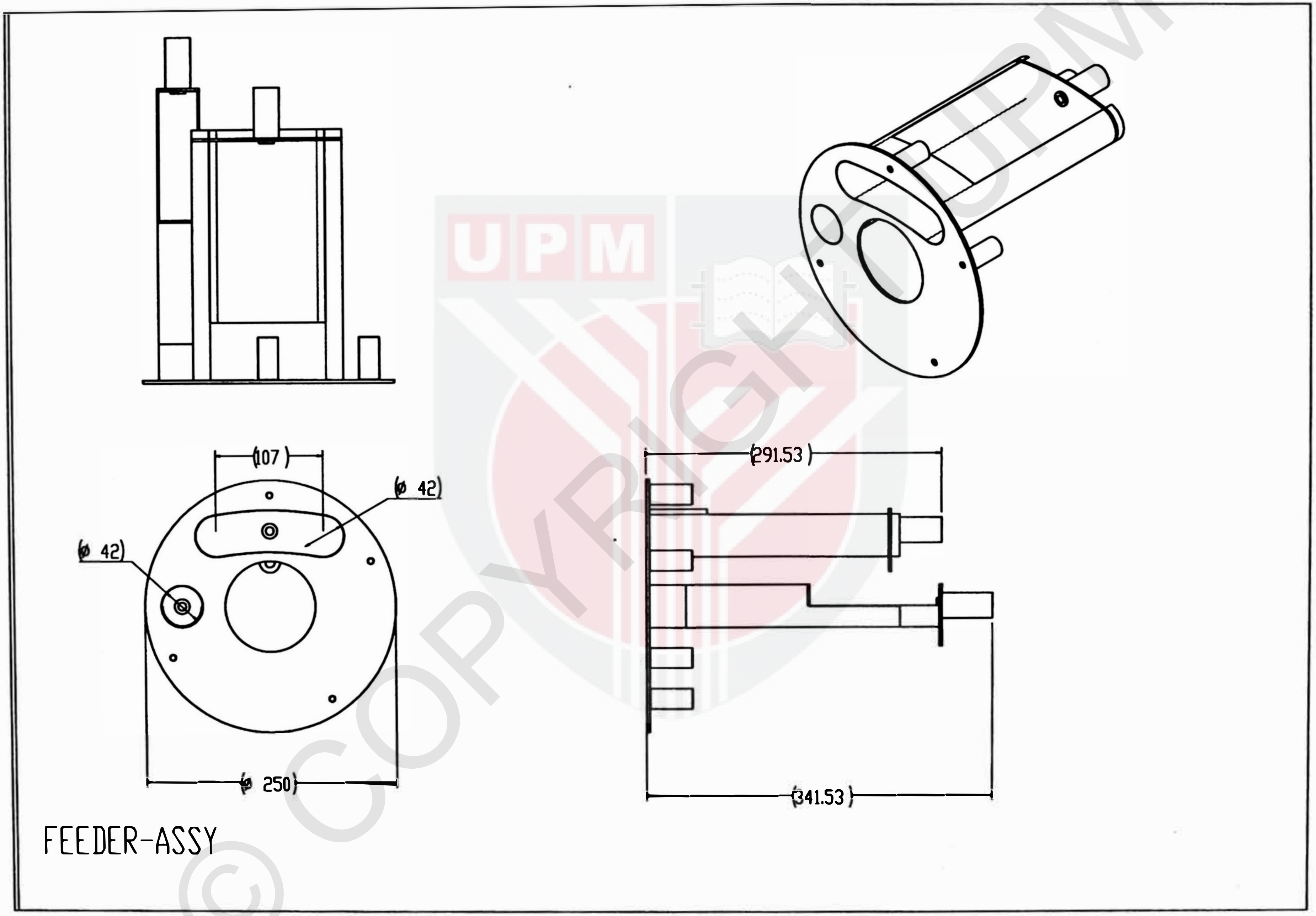


TOP VIEW OF BANANA SLICER MACHINE

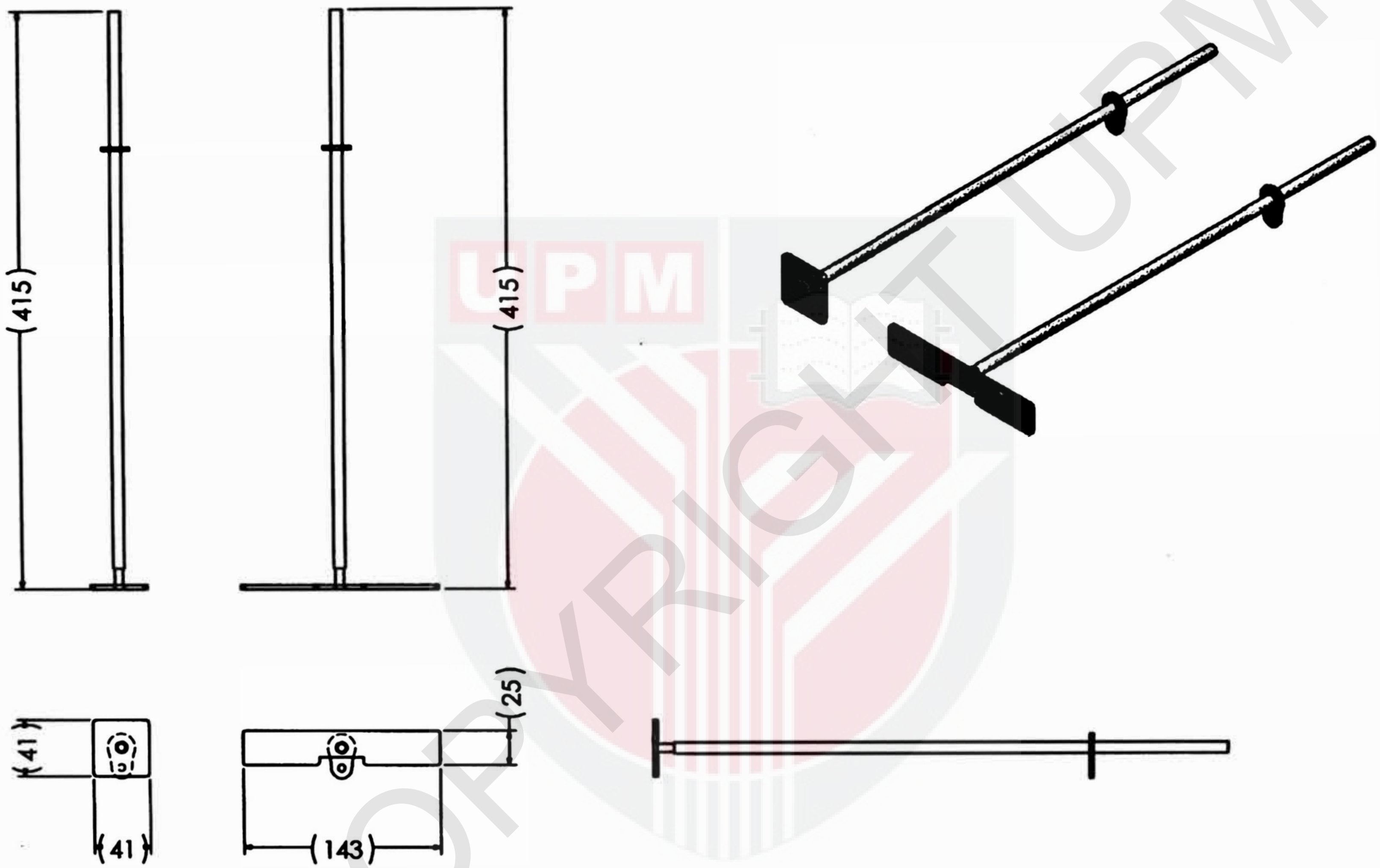


BACK VIEW OF BANANA SLICER MACHINE

APPENDIX B

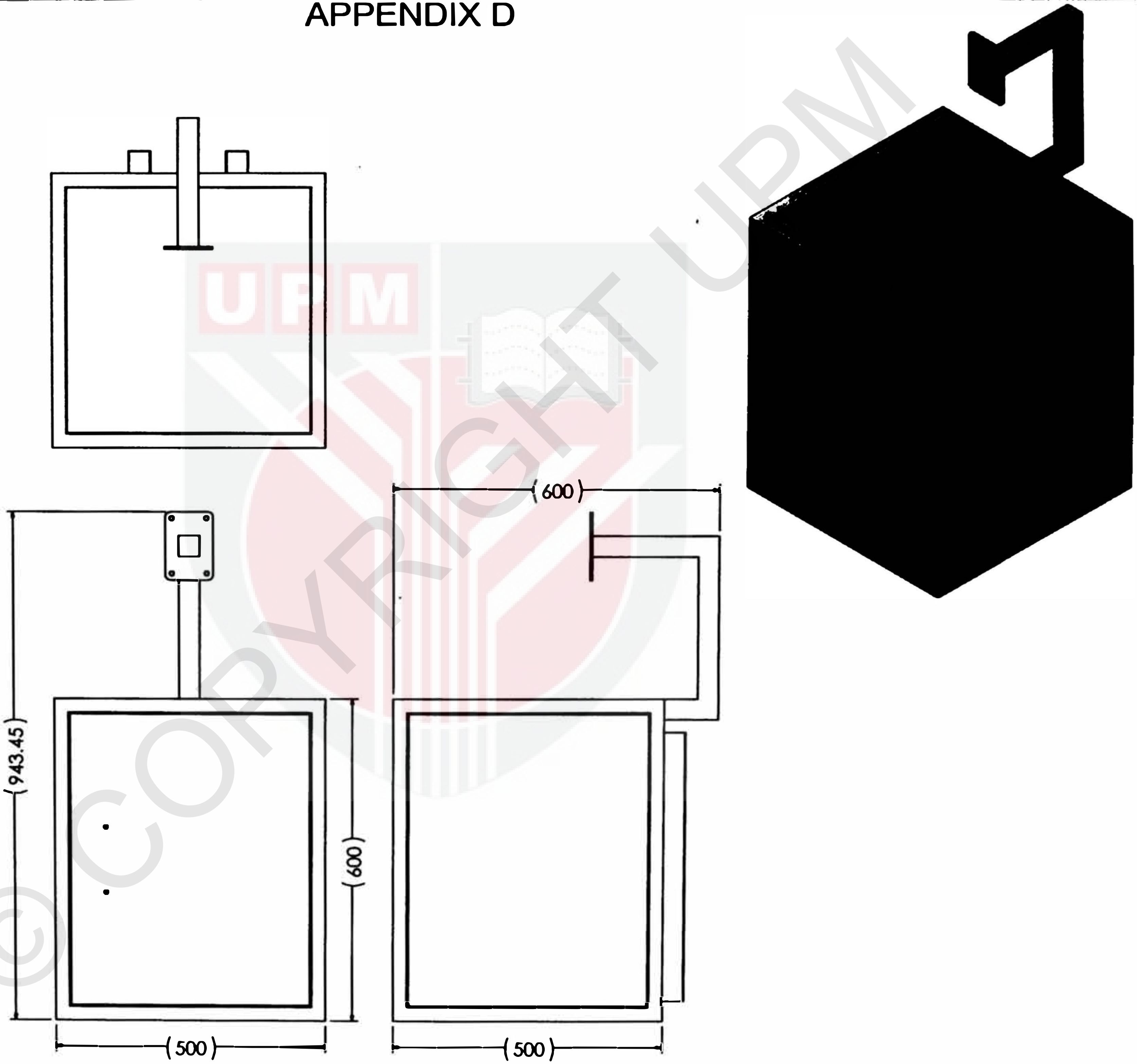


APPENDIX C



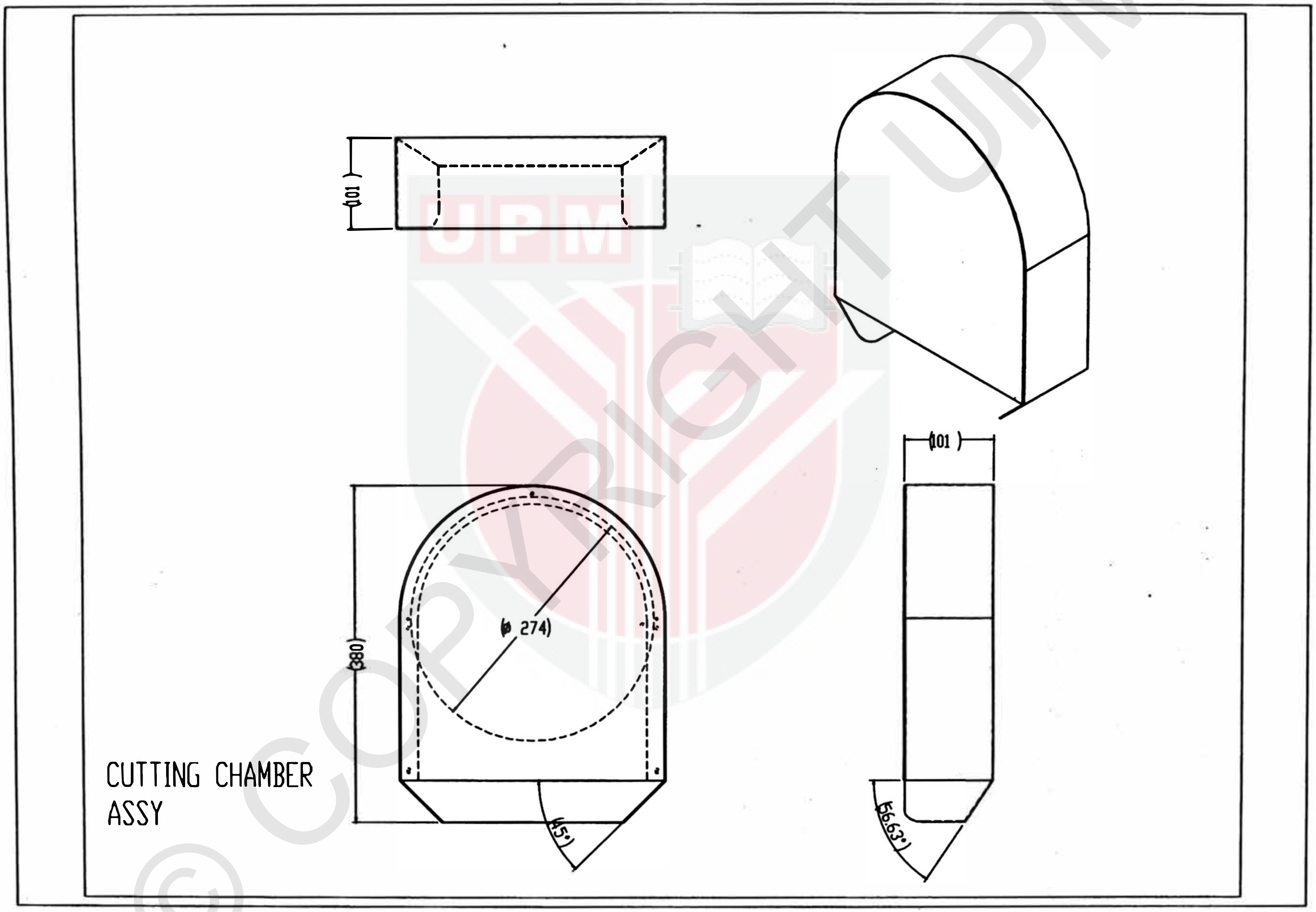
PUSHER-ASSY

APPENDIX D



CABINET-ASSY

APPENDIX E



APPENDIX F

Data for determine size of banana

Sample	Length without skin (mm)		Diameter without skin(mm)					Weight without skin (g)
	straight	curve	Point c	Point d	Point e	Point f	Point g	
1	95	103	34	42	40	39	33	30
2	102	104	31	30	30	29	28	33
3	102	104	31	31	40	37	29	27
4	102	103	31	32	32	32	32	26
5	102	103	28	31	34	35	30	27
6	102	103	34	35	35	35	34	25
7	105	103	38	39	40	40	30	35
8	102	104	33	35	37	37	31	30
9	102	104	33	35	34	33	32	30
10	101	104	32	37	36	35	33	30
11	155	144	30	31	36	27	29	80
12	180	135	32	35	35	34	31	75
13	175	149	30	34	37	34	31	85
14	160	138	30	30	34	31	31	80
15	184	126	31	31	32	32	31	70
16	150	135	28	31	32	33	32	75
17	192	140	29	32	31	32	26	75
18	170	135	26	30	30	31	30	65
19	148	138	31	32	33	35	33	85
20	176	126	30	30	31	31	30	65
Mean	135.2	120.0	33					52
Max	192	149	43					85
Min	95	103	26					25
Std	36	18	3					24

Data for time taken for 1 tube of banana to be sliced

No. of of testing	Circular feeder Time taken (s)	Circular feeder Weight (g)	Longitudinal feeder (Horizontally) Time taken (s)	Longitudinal feeder (Horizontally) Weight (g)
t_1	12	21	8	34
t_2	13	25	7	25
t_3	12	20	7	24
t_4	12	23	9	25
t_5	11	18	8	27
t_{ave}	12	21	8	27

Data for the production rate of sliced banana in g/s and kg/hr

Type of feeders	Production rate $\dot{m}\left(\frac{g}{s}\right)=\frac{W}{t}$	$\dot{m}\left(\frac{kg}{hr}\right)=\frac{W\times\frac{1kg}{1000g}}{t\times\frac{1\,hr}{3600s}}$
Circular	4.7	16.9
Longitudinal(Horizontally)	3.4	12.2

Data for capacity production banana arranged vertically in longitudinal feeder to be slice

	No of sample	Time taken, t (s)	Weight, W (g)
	4	20.3	188
	5	37.0	159
	4	17.0	135
	5	12.0	104
	5	18.4	164
Mean	5	20.9	150

$$\dot{m}\left(\frac{g}{s}\right)=\frac{150\,g}{20.9\,s}=7.2\,g/s$$

$$\dot{m}\left(\frac{kg}{hr}\right)=\frac{150\,g\times\frac{1kg}{1000g}}{20.9\,s\times\frac{1hr}{3600s}}=25.92\,kg/hr$$

Data for capacity productio of multi-food solid

Time taken for a load of cassava was sliced

No of testing	Cassava			
	Circular Feeder		Longitudinal Feeder	
	Time taken, t (s)	Weight, W (g)	Time taken, t (s)	Weight, W (g)
t_1	10.2	29	18	41
t_2	12.5	39	15	59
t_3	12.6	76	14	57
t_4	19.3	80	15	60
t_5	15.6	57	12	50
t_{ave}	14.04	56.2	15	53.4

Time taken for a load of sweet potato was sliced

No of testing	Sweet potato			
	Circular Feeder		Longitudinal Feeder	
	Time taken, t (s)	Weight, W (g)	Time taken, t (s)	Weight, W (g)
t_1	12.2	54	10	73
t_2	12.5	41	13	62
t_3	12.6	75	16	70
t_4	19.3	80	16	67
t_5	14.1	78	20	70
tave	14.1	66	15	68

Time taken for a load of carrot was sliced

No of testing	Carrot			
	Circular Feeder		Longitudinal Feeder	
	Time taken, t (s)	Weight, W (g)	Time taken, t (s)	Weight, W (g)
t_1	15.3	60	9	70
t_2	15.9	53	8	57
t_3	20.0	80	9	97
t_4	12.5	37	9	68
t_5	11.2	50	6	63
tave	15.0	56	8	71

The production rate of food products in g/s and kg/hr

Types of food products	Production rate			
	Circular feeder		Longitudinal feeder	
	$\dot{m}\left(\frac{g}{s}\right) = \frac{W}{t}$	$\dot{m}\left(\frac{kg}{hr}\right) = \frac{W \times \frac{1kg}{1000g}}{t \times \frac{1hr}{3600s}}$	$\dot{m}\left(\frac{g}{s}\right) = \frac{W}{t}$	$\dot{m}\left(\frac{kg}{hr}\right) = \frac{W \times \frac{1kg}{1000g}}{t \times \frac{1hr}{3600s}}$
Cassava	4.0	14.4	3.6	12.96
Sweet potato	4.6	16.6	4.6	16.56
Carrot	3.7	13.3	8.8	31.68

Data for average thickness of sliced banana in circular and longitudinal shape

No. of testing	Thickness (mm)				
	Circular shape	Longitudinal shape			Mean
1	1.0	1.1	1.1	1.2	1.1
2	1.0	1.3	1.0	1.0	1.1
3	1.2	1.1	1.1	1.0	1.1
4	1.2	1.3	1.1	0.9	1.1
5	1.4	0.8	1.1	0.8	0.9
6	0.7	1.1	0.9	1.0	1.0
7	1.0	0.8	0.8	0.8	0.8
8	1.0	1.0	1.0	1.0	1.0
9	0.9	0.9	0.9	0.9	0.9
10	1.0	1.2	1.0	1.0	1.1
11	0.8	1.1	1.0	1.1	1.1
12	1.0	1.0	1.0	1.0	1.0
13	1.0	1.3	1.1	1.1	1.2
14	1.0	1.2	1.1	1.0	1.1
15	1.0	1.0	1.2	1.0	1.1
16	0.9	0.9	1.0	0.9	0.9
17	1.0	1.1	1.1	1.1	1.1
18	0.8	1.1	1.1	1.0	1.1
19	0.9	1.1	1.1	1.0	1.0
20	1.0	1.2	1.3	1.0	1.1
21	0.8	1.0	1.2	1.1	1.1
22	1.0	1.0	1.4	0.9	1.1
23	1.0	1.0	1.1	1.2	1.1
24	1.0	1.0	1.1	1.2	1.1
25	0.9	1.9	1.3	1.9	1.7
26	0.7	1.3	1.1	1.4	1.3
27	0.8	1.4	1.0	1.0	1.1
28	0.9	1.1	1.1	1.1	1.1
29	1.0	1.2	1.2	1.1	1.2
30	1.1	0.9	1.1	0.9	1.0
Mean	1.0				1.1
Std	0.1				0.1