UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF DABAI NUTCRACKER

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ABSTRACT

The design and development of the dabai nut cracker is purposely to help the promotion of dabai fruits where it is until now still considered as an underutilized fruits because of lack of research studies on the fruits itself. The design mainly is to help the worker to crack the seeds of the dabai fruits where the nuts inside the seed can be obtained. The design is to help in solving the difficulties in cracking the nuts of Dabai fruits, difficulties in accessing the whole kernel when using ready stock nutcracker because the uniqueness of the shape where it has triangular/oval shape and the shell is very hard to rupture. Other problem to be solved with this design is to get a specific nut cracker for Dabai nut. The nuts from the seeds can also be consumed as it tastes like peanuts. There are also recent findings indicates that the nutritional quality of the nut is most likely to be similar to the composition of palm oil such as the palmitic acid, linoleic acid, and linolenic acid. The main objective of this project is to design and evaluate the performance of the device itself and also develop the device if there is any improvement or modification that can apply more to the design. The details design drawing is made using the SOLIDWORKS software as the main platform as it is the most suitable software in drawing the design of tool. The fabrication of the device is being done and performance test is carried out to determine the production capacity and efficiency of the tool. The dimension of the tool is 351 mm (upper part length) x 250 mm (bottom part length) x 144.09 mm (height) x 100 mm (width). The desired results from the tool are the kernel of dabai nut in a whole and all the shells is separated from it. The performance capacity of this tool is 1.64 kg/hr. Dried Dabai nut will load to the jig holder according to its sizes. The sizes has been determined to be big and small size.

The jig holder slide into the bottom dies. The top die cracks the nut when is pressed by the roller when it is in touch with the press handle. After cracking process of the nuts, the jig holder is removed and the kernel is separated from the shell. When the nut is removed from the jig holder, the kernel will detached from the shell. The most important features of this tool are it has a jig to holds Dabai nut accordingly to the unique shape of the nut compared to other general nutcracker exist in the market. The tool gives 97.27 % in overall efficiency and because of this high performance of the machine, it would help to cracking Dabai nuts for retrieving the kernel for further process especially in producing alternative cooking oil that have high potential to burst into market to stand along others cooking oil in Malaysia. Furthermore, all objectives of this project has been successfully determined.

ABSTRAK

Reka bentuk dan pembangunan pembuka biji dabai untuk membantu promosi buah dabai di mana ia kini masih dianggap sebagai buah-buahan yang kurang dimakan kerana kekurangan kajian penyelidikan tentang buah itu sendiri. Reka bentuk utamanya adalah untuk membantu pekerja memecahkan biji buah dabai di mana kekacang di dalam benih itu boleh diperolehi. Kekacang dari benih juga boleh dimakan dan rasanya seperti kacang tanah. Terdapat juga penemuan baru-baru ini menunjukkan bahawa kualiti nutrisi kekacang mungkin sama dengan komposisi minyak sawit seperti asid palmitik, asid linolik, dan asid linolenik. Objektif utama projek ini adalah untuk merekabentuk dan menilai prestasi peranti itu sendiri dan juga membangunkan peranti ini jika terdapat penambahbaikan atau pengubahsuaian yang boleh membantu peranti menjadi lebih baik. Reka bentuk ini akan direkabentuk dengan menggunakan perisian SOLIDWORKS sebagai platfom utama untuk lukisan reka bentuk yang akan dibuat kerana ia adalah perisian yang paling sesuai untuk mereka bentuk peranti tersebut. Pembuatan peranti yang dilakukan dan ujian prestasi telah dijalankan untuk menentukan keupayaan dan kecekapan pengeluaran alat tersebut. Dimensi alat ini ialah 351 mm (panjang bahagian atas) x 250 mm (panjang bahagian bawah) x 144.09 mm (tinggi) x 100 mm (lebar). Hasil yang diingini dari alat ini adalah inti dari kacang dabai secara keseluruhan dan semua kulit kacang berjaya dipisahkan dari kernel itu. Kapasiti prestasi alat ini ialah 1.64 kg / jam. Kacang Dabai kering akan dimuatkan ke pemegang jig mengikut saiznya. Saiznya telah ditentukan untuk saiz besar dan kecil. Kacang buah Dabai akan dimasukkan ke slider pemegang jig ke bawah top die. Top die akan

memecah kacang apabila ditekan oleh roller apabila ia berhubungan dengan pemegang tekan. Selepas proses pemecahan, pemegang jig dikeluarkan dan kernel dipisahkan dari kulit kacang. Apabila kacang dikeluarkan dari pemegang jig, kernel akan terlerai dari kulit kacang. Ciri-ciri yang paling penting dari alat ini adalah ia mempunyai jig untuk memegang kacang Dabai sesuai dengan bentuk kacang yang unik berbanding dengan pemecah kacang umum lain yang wujud di pasaran. Alat ini memberikan 97.27% dalam kecekapan keseluruhan dan kerana prestasi tinggi mesin ini, ia akan membantu memecahkan kacang Dabai untuk mendapatkan semula kernel untuk proses selanjutnya terutamanya dalam menghasilkan minyak goreng alternatif yang berpotensi tinggi untuk meletupkan pasaran untuk berdiri bersama orang lain minyak masak di Malaysia.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Dabai Fruit (*Canarium odontophyllum)*

Figure 1.1 *Canarium odontophyllum* (Dabai) fruit (Sidek, n.d.)

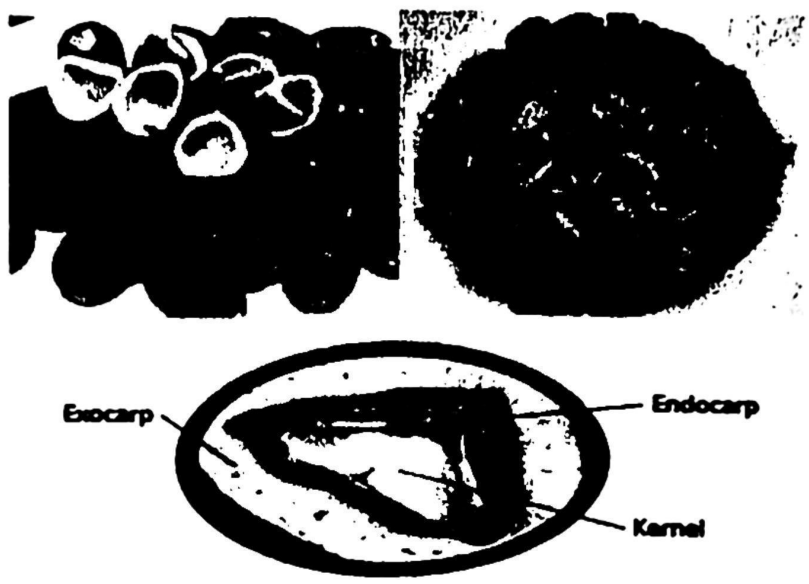
Canarium Odontophyllum Miq. (Figure 1.1) commonly known as Dabai, is one of the mainstream underutilized products of Sarawak, Malaysia. Sarawak is a state situated in Borneo Island that rich with underutilized leafy foods which grows wild around the range of Iban community. Neighborhood people group expends a lot of Dabai amid the organic product aging season without knowing much about its well-being advancing properties. Numerous research of Dabai fruits nutritional values has

been carried out, in different region of Sarawak where a significant findings shows the existence of cancer agent properties lies in the fruit (Lim, 2012). Dabai is a seasonal organic product that is accessible just amid the periods of October to December.

Dabai is an organic product which belongs to Burseraceae family which comprises of 100 species conveyed all through tropical Africa, Asia, and the Pacific island. The organic product is oval fit as a fiddle, rich wellspring of protein, fat, sugars, and minerals (sodium, calcium, and iron). The fat substance is like that of olive and avocado organic products.

The mature Dabai fruit is dim purplish in colour. In Malaysia, Dabai has been named underutilized products of the soil recorded as plant hereditary assets for nourishment agribusiness in Sabah and Sarawak. The oval shape fruit measures at 3.75±0.1 cm in length, 2.4±0.19 cm in diameter and weighing 11.1±1.5 g in average (Shakirin *et al.* 2010).

This fruit is very hard to eat if consumed without soaking it in warm water. Usually, after a few minutes of soaking, the fruit becomes softer and the taste is very creamy when eaten. However, the local people in Sarawak eat the fruit with a little bit of salt or sugar to make it more delicious. Alternatively, the fruit can be processed into a pickle product. The fruit is poor in ascorbic acid but rich in minerals such as potassium (352 mg/100 g), phosphorus (65 mg/100 g), calcium (200 mg/100 g) and magnesium(106 mg/100 g) (Shakirin, *et al.*, 2012).



Dabai fruit (upper left), dabai nut (upper right), and cross section of fruit (lower)

Figure 1.2 Dabai fruits, nuts and kernel (Brooke, n.d.)

Dabai organic products are high in cancer prevention agents' particularly phenolic acids, flavonoids and anthocyanin. Phenolic mixes have been observed to be extremely valuable for ceaseless ailments, for example, malignancy, coronary illness and diabetes and they are additionally mitigating and hostile to microbial. It additionally has advantageous cholesterol bringing down and plaque-lessening impacts.

According to (Shakirin *et al.*, 2010), about 21–25%of canarium pulp and 70% of its kernel are composed of fats, especially SFAs that make up 44.4% of pulp oil and 70% of kernel oil. The extracted crude oil has a yellowish color and is semi-solid in room temperature. The 16:0 and 18:0 are the major fatty acids in canarium oil, a characteristic which is similar to palm oil.

Moreover, this oil contains large amounts of vitamin E as well as phenolic compounds which are associated with substantial antioxidant activities. Canarium pulp oil had been found to protect hypercholesterolemia rabbits against cardiovascular risk

because of its high phenolic contents. This oil is also used to heal wounds and burns. Canarium oil is also considered as healthy cooking oil.

For commercial uses, Dabai has been turned into several products. Dabai soap, Dabai paste, hot and spicy Dabai sauce, Dabai mayonnaise, Dabai Pizza, Dabai fried rice, Dabai keropok or crackers, Dabai layer cake and cookies

1.2 Market prospect of Dabai fruit in Malaysia

The price of Dabai fruits is roughly RM40 per kilogram when there is high demand of the product in the market. These situations occur especially during the peak season of Dabai fruit. Also known as the Zaitun Sarawak or in its scientific name '*Canarium Odonthopyllum*', the organic product is a span of a thumb that tastes sweet and greasy, is dependably an enthusiast of the amusement.

Figure 1.3 Photo of Dabai sellers in Kapit, Sarawak (Abd Manaf, 2011)

Despite of being productive in specific seasons, numerous Dabai can be found across Sarawak which is in Sibu, Sarikei and Kapit. This can be of an awesome advantage to its business people as a solitary tree can produce approximately 30 to 80 kilograms contingent upon development or in other words when the tree are fully matured. The Dabai fruit lover was once in the past prevalent just by the Iban people group before it was well known among Malays and Chinese.

Scientific research on Dabai found, notwithstanding containing protein, vitality and minerals, for example, potassium and calcium. These organic products are likewise rich in cancer prevention agent nutritious body content as specified in the past area of the theory. Despite the fact that it is just regular and it must be discovered once per year, it can produce lucrative salary for Dabai nursery workers. Some can earn from RM28, 000 to RM50, 000 a year. By developing Dabai fruit, producers or agriculturists can expand their financial occasionally.

Table 1.1 Composition of Dabai Fruit Ingredients (Hun *et al.*, 2014)

Composition	Contents (per 100 g)		
	Pulps	Skins	Kernel
Moisture (g)	52.51	63.28	45.38
Protein (g)	4.77	6.40	9.02
Fats (g)	18.90	12.37	28.16
Carbohydrate (g)	22.07	15.46	14.91
Ash (g)	1.77	2.50	2.54
Dietary fiber(g)	13.38	18.81	10.05
Energy (kcal)	371.12	330.44	419.51

Dabai fruit can always eats raw. Development products based on Dabai not yet fully explore. As a seasoned fruit, Dabai can only be sold at a high price on early season. However, during peak season, overload of fruits will cause drastic declination in the market prices. Therefore, the technique of addition value is needed as a step settlement of impairment on the side increase the use of Dabai. Potential value added products to be produce rather than fruit of Dabai itself including fruit and cool frozen pulp, fruit juice drinks, mayonnaise, crackers, sauce, and flavoring paste for cooking. Then again, cocoa butter is a sort of vegetable fat acquired from the cocoa bean. The unsaturated fat organizations of oil extricated from Dabai portion are tantamount with cocoa butter. In this way, Dabai kernel oil can possibly be produced as an option for cocoa butter. In the interim, the high phytochemicals substance found in this organic product makes it appropriate to be created as a natural product sauce. (Tan and Azrina, 2016)

Dabai fruit has the potential to be utilized as many end product as it can. The use of Dabai in product development as new food can diversify its uses and ensuring the supply of this fruit in the off-season. This is all at once developing local fruit processing industry and in the same time develops the marketability of Dabai fruits and its development product as well.

1.3 Dabai Fruits as Alternative Cooking Oil

In Malaysia, palm oil is commonly used due to its superior frying quality and oxidative stability owing to high content of monounsaturated and saturated fatty acids. The fatty acid compositions of Dabai pulp oil were characterized by a near equal percentage of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA), at about 40% and also polyunsaturated fatty acids (PUFA) at about 12% to 13%. These demonstrate that Dabai mash oil may have practically identical healthful substance, as the palm olein, which has been broadly acknowledged and utilized as cooking oil in different sustenance applications in Malaysia and numerous different nations. This data likewise proposes that Dabai mash oil could be an option cooking oil sooner rather than later. (Azlan *et al.*, 2010)

1.4 Introduction to Nut Cracker

A nutcracker is an apparatus intended to open nuts by separating their shells. There are many design, including levers, screws, and ratchets. An outstanding sort depicts a man whose mouth frames the jaws of the nutcracker. However a considerable lot of these are implied for improving use.

Nuts were verifiably opened utilizing a sledge and blacksmith's iron, regularly made of stone. Some nuts, for example, walnuts can likewise be opened by hand, by holding the nut in the palm of the hand and applying pressure with the other palm or thumb, or utilizing another nut. Manufacturers create useful nutcrackers nowadays shape like a pincers, yet with the rotate point toward the end past the nut, instead of in the

center. These are additionally utilized for breaking the shells of crab and lobster to make the kernel inside accessible for eating.

A nutcracker tool has been widely used not just in Malaysia. Usually it is used as kitchen appliances for housewives to crack open a nuts such as walnuts. It helps in consuming energy and time. Sometimes, consumer will be having trouble with solid hard nuts when compared to softer shell nuts. The traditional ways of cracking nuts are using bare hands. Unexceptionally, this old method may cause slight injury to the hands if the shell penetrates into the skin. This will occasionally effected the outcome of the nuts and could cause contamination when expose to blood due to hand injury.

The invention of nutcracker has been evolving through times. Sticking to the same principal and concept of cracking nuts however, there are many design of nutcracker that available nowadays. There are also ways to crack a nut using magnetic methods where iron powder and magnetic fluids are used to separate the shells and kernel of a walnut (Berlage, 1984) . However in Malaysia, we can only find general nut cracker, walnut's nutcracker and several other nutcracker designs specifically for certain type of nuts. There is no significant designed nutcracker for Dabai fruit nut. This is because Dabai fruit is not a major fruit consume by people around the world compared to other type of nuts. Other than that, Dabai fruit is not a famous fruit among Malaysian, but the truth is, it's undiscovered nutritional that lies in the nut of Dabai fruit is not well-known by the community itself. This cause the farmers of Dabai fruit to throw away the nuts of Dabai fruit after the skin and flesh of the fruits is obtain, making the Dabai fruit considered as one of the underutilized fruit for human nutrition and sustainable diets (Lim, 2012).

1.5 Problem Statement

Dabai seed paste is used as cocoa butter substitute to produce dark chocolate. A study reported that the best formulation was selected after a few hedonic tests. The formulation consisted of 50% chocolate, 45% Dabai seed paste, 35.25% sugar, 17% water, 2.5% butter and 0.25% citric acid. Besides, chocolate truffle with Dabai ganache can also be produced using Dabai puree. In future, the use Dabai or other local fruit as an additional ingredient in developing chocolate-based products can increase the variety of chocolate products in Malaysian market (Azlan, 2017).

Dabai fruit is a potential fruit with double set of benefits, which its lipids tend to produce a better blood lipid profile while the high content of phenolic compounds gives antioxidant effects. There are several products (mayonnaise, sauces, chips, pickles and soap) have been developed from this fruit for local markets. This fruit has also been used by local restaurants as ingredient in their dishes (Lim, 2012)

Some industrialist or smaller context which is farmers take this issue as a small problem because it seem that they did not realize the potential of the nut's nutritional value that could possibly give their business or company a major impact as it can be value added to most product because of its nutrition. Therefore growing knowledge sharing has been done to the community of Dabai fruit producers and consumers to make them realize the importance of utilizing the Dabai fruit.

However in order to retrieve the nut kernel from the shell they will stumble across the difficulty of cracking the shell of the Dabai fruit nut. Common problems when cracking the nut shell and accessing the nut kernel or the kernel without harming the nut

kernel is a challenge. The commercialize nutcracker are not suitable to be used in the small & medium industries as it is only design for kitchen used. Other than that, past design of nutcrackers have complexity and do not provide good cracks and often damages the nut kernel or the kernel of the nut. Therefore, new design of nutcracker need to be design so that it can be implement to the industry as one of the major tool to assist cracking the shell of Dabai fruit nut efficiently.

Therefore, the specific problem statements are as follows:

i. Difficulties in cracking the nuts of Dabai fruits.

ii. Difficulties in accessing the whole kernel as in one piece when cracking using ready stock nutcracker because the uniqueness of the shape where it has triangular/oval shape and the shell is very hard to rupture.

iii. No suitable cracker especially for Dabai nut is presence.

1.6 Objectives

The objectives of the project are:

i. To determine some Physical and Mechanical Properties of Dabai Nut (***Canarium odontophyllum)***

ii. To develop and fabricate a Dabai Nutcracker

iii. To evaluate the performance of a Dabai Nutcracker

1.7 Scope of Study

Scope of the study of this project includes:

i. Development of this device for small scale industries

ii. The device is practical and user friendly

iii. The device can also be used for other type of nuts having similar shape.

CHAPTER 2

LITERATURE REVIEW

2.1 Plant Description and Development of *Canarium odontophyllum*

Dabai (*Canarium odontophyllum*) is an indigenous occasional organic product which develops normally in the wild and must be found in Borneo Island, particularly Sarawak. It is ordinarily known as 'Sarawak olive' because of its likeness to olives. Nonetheless, it is not organically identified with the olive family. It is additionally called 'Sibu olive' since it is found in plenitude along the along the Rajang River bowl, particularly in Sibu divisions in Sarawak.

Dabai trees are androdioecious, which means they offer ascent to either male or bisexual trees (bearing blossoms with both male and female parts). Just bisexual trees prove to be fruitful, this implies that planting from seeds which is regularly honed by agriculturists can offer ascent to male trees which don't create organic products. These male trees must be affirmed from their blossoms, when they come into blooming following 8-10 years. Once the male trees can be distinguished, most ranchers will expel

them and just keep up the bisexual trees. In this manner, to overcome this vulnerability on the plant sex, ranchers normally plant at least two seedlings at one point and hold just the bisexual plants. Because of this reason, vegetative spread of bisexual trees by means of maturing is prescribed. Sprouted bisexual trees come into bearing prior at around 5 years of development. Then again, bisexual trees developed from seeds will take around 6 to 8 years to bloom and set natural product. (Brooke and Yuon, 1980)

Being a prevalent indigenous natural product in Sarawak, Dabai can possibly be promoted as claim to fame organic product since it has likewise been distinguished as a Geographical Indication product as mention by MARDI. Today, Dabai is broadly developed in farm plots everywhere throughout the state of Sarawak. Recent investigations of Dabai are very much recorded and business planting utilizing prevalent and chose quality material is promising. The possibility of developing Dabai as a monetary product in the state is splendid effort in return.

The Research Division of Department of Agriculture Sarawak has done field evaluation of numerous selections of Dabai obtained from different regions in Sarawak since the late 1980's. This varietal selection work has resulted in the selection of two superior clones, namely Laja and Lulong which are highly recommended for commercial planting. Cross section of the fruit shows that seed of Laja is triangular with concave sides while the seed of Laja is more rounded or convex on its sides. (Brooke and Yuon, 1980) Figure below shows the fruit section of the two different species of Dabai fruits that has been cultivated in Sarawak for the past few years.

(i) (ii) (iii)

Figure 2.1 Fruits of Canarium odontophyllum (i), pulp (ii), and seed (iii)

Source: (Azlan, 2017)

Dabai trees are androdioecious, meaning they give rise to either male or hermaphrodite trees (bearing flowers with both male and female parts). Only hermaphrodite trees bear fruit, this means that planting from seeds which is commonly practiced by farmers can give rise to male trees which do not produce fruits. (Brooke and Yuon, 1980) These male trees must be affirmed from their blossoms, when they come into blooming following 8-10 years. Once the male trees can be distinguished, most agriculturists will evacuate them and just keep up the bisexual trees.

Accordingly, to conquer this vulnerability on the plant sex, agriculturists as a rule plant at least two seedlings at one point and hold just the bisexual plants. Because of this reason, vegetative spread of bisexual trees by means of growing is suggested. Grown bisexual trees come into bearing before at around 5 years of development. Then again, bisexual trees developed from seeds will take around 6 to 8 years to blossom and set natural product.

Figure 2.2 A Fully grown Dabai Tree (Brooke and Yuon, 1980)

2.2 Properties Dabai Fruit *(Canarium Odontophyllum)*

According to (Azlan *et al*, 2009) the importance of dimensions is in determining the aperture size of machines, particularly in separation of materials. When the dimensions are obtained, it can be used in designing machine components and parameters. Figure below is some properties of Dabai Fruit (*Canarium Odontophyllum*). They have classified the size of the fruit into two different sizes which is big and small size. Table 2.1 below shows the readings of the properties of both big and small size of *Canarium Odontophyllum* fruit.

Table 2.1 Some Properties of Dabai Fruit (*Canarium Odontophyllum*) with standard deviation (Azlan *et al.*, 2009)

Property	Mean (± Standard deviation, SD)	
	Bigger size	Smaller size
Length (cm)	4.10 (± 0.11)	3.74 (± 0.08)
Width (cm)	2.79 (± 0.13)	2.40 (± 0.07)
Mass (g)	18.28 (± 1.59)	12.73 (± 0.69)
Mass (g) of fraction:		
Skin	1.02 (± 0.19)	0.86 (± ND)
Flesh	11.2 (± 0.93)	7.81 (± ND)
Kernel	6.79 (± 0.81)	5.84 (± ND)
Thickness (cm)	0.5 (± 0.0)	0.4 (± 0.00)
Sphericity index, S_c (%)	43.62 (± 0.76)	41.28 (± 0.69)
Aspect ratio, R_a (%)	67.37 (± 4.23)	65.79 (± 2.26)

*ND – not determined

Figure 2.3 Dimensions of typical dabai nut

2.3 Review of Nut Cracker Tools in Market

The access of the whole kernel from Dabai nut is still floundering issues. Therefore, there are no specific tools invented for the processing and handling of Dabai nuts. In consideration of this particularly raising issue and also the increasing attention in the kernel properties of Dabai that has similarities to cocoa butter, the tools used for material handling such as Dabai nutcracker tools is needed right away to replace the conventional cracking method of using small kitchen tool such as typical home nutcracker.

For the time being, there has been lack of development of commercialize Dabai nutcracker existed in the industries. However there are similar nutcracker tools used for cracking walnuts, pecan nuts, and macadamia nuts. However from preliminary studies shows that normal nutcracker tools have failed to crack Dabai nut as it has extremely hard shell. Figure below shows the broken universal nutcracker used to crack Dabai nuts. There are few nutcracker tools found in the market currently but not fabricated in Malaysia.

2.3.1 Estillo Heavy Duty Pecan, Nut and Seafood Cracker

The product is made from solid zinc. It is constructed for the purpose of cracking nuts and seafood. It is designed to fit all sizes of nuts. Furthermore, it is BPA free and dishwasher safe. The mechanism includes hinge that can be reinforced for additional strength and also designed to be ergonomic for easy cracking purposes. Other than that, the advantages of this product is that it is suitable to be used to crack Lobster, Seafood, Shell Fish, Oysters, Crab Shells and most type of nuts. The dimensions of the product are approximately 6.0 x 0.2 x 1.5 inches and weighing at 1.6 ounces.

Figure 2.4 Estillo Heavy Duty Pecans, Nut and Seafood Cracker

This is the most common nut cracker that can be found in the market as it is very light in weight to help its mobility of the product to be transferred or carried to anywhere the user wants. Lastly it has one of the lowest prices on the market.

2.3.2 The Texan York Nut Sheller – Nut Cracker

The dimensions of the product are 2.0 x 5.5 x 9.5 inches and weigh at 6.4 ounces. This nut cracker is manufactured by Texan Nut Sheller originated from San Angelo, Texas, United States of America (USA).

Figure 2.5 The Texan York Nut Sheller – Nut cracker

The advantages of this product can be viewed from its simplicity design. Although it looks simple however it is effective enough for cracking nuts. The product is made from tempered steel for a specific purpose without any exaggeration or unimportant extra parts. The design enables the enhancing to crack open most nuts with ease compared to other conventional crackers. Other than that, less force is needed to be applied to do the job of cracking nuts. Lastly it looks elegance especially in terms of its colour.

However there are some disadvantages of this product. One of it is easily worn out and fits to a bigger size of nuts. This is due to the design of the cutting plates which is slightly shallower compared to other nut cracker. Moreover the cutting plate is easily worn out if not taken care very well and needed to replace with new cutting plates.

2.3.3 Heavy Duty Pecan Nut Cracker

This is a product made and mounted on a hardwood base. Has a heavy and strong base form. It is made to ease the cracking of nut, includes pecan, hazelnuts, almonds, walnut, Brazil nut and more. The cracking part is constructed from steel with nickel plated, makes it durable and able to withhold wear and tear. The dimension of this product is 8.5 x 2.7 x 2.5 inches and weigh at 1.41 pounds.

Figure 2.6 Heavy Duty Pecan Nut Cracker

The advantages of this product are that it can be used to crack open several type of nuts and not design specifically for one type of nut making it a universal nut cracker. Other than that, it has strong base to hold the frame of the product so that when the product can be used without slipping from its place. However there are some disadvantages as this products cost a little bit high, and from an unknown sources, the production of this product has been

.

2.4 Patent Search

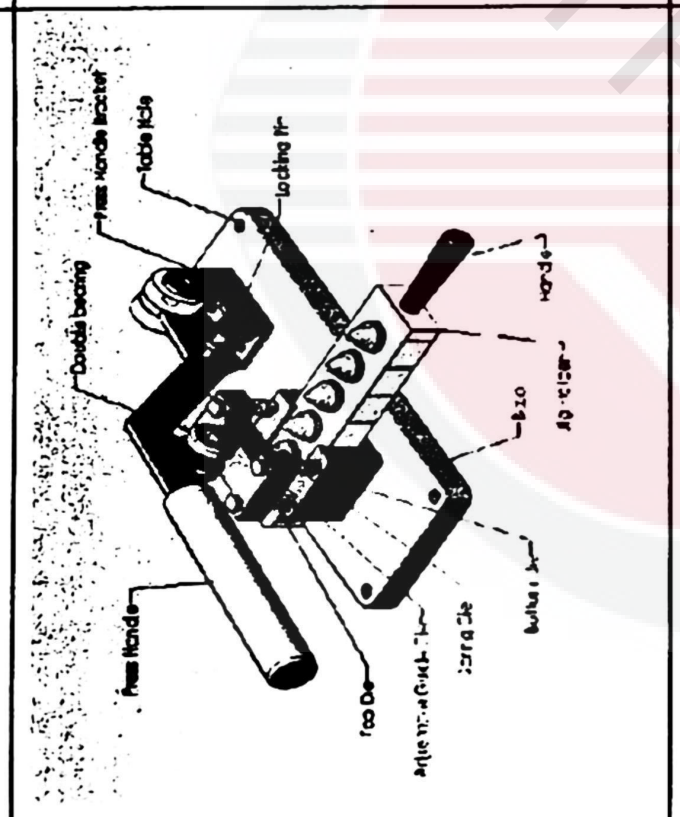
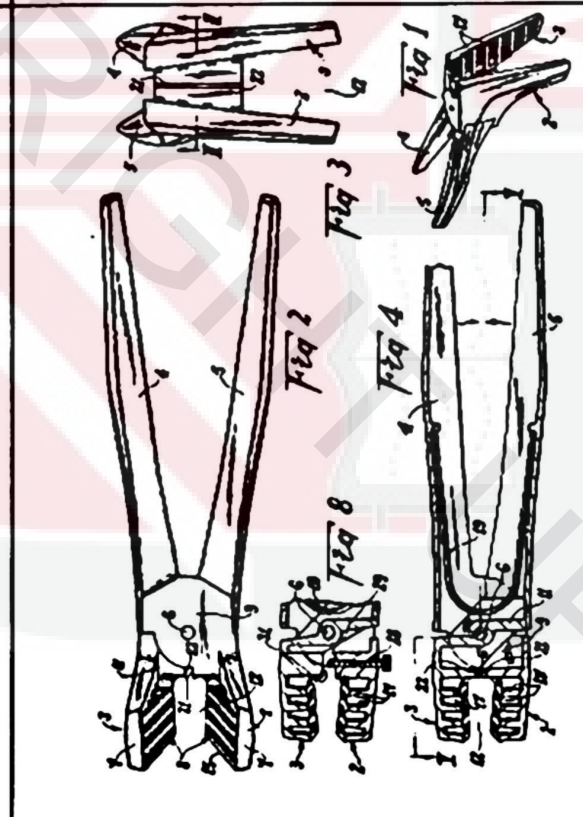
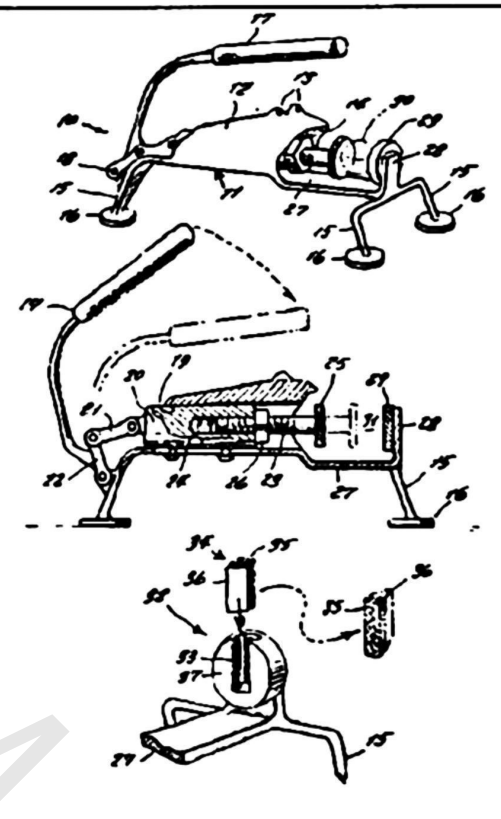
Patents are type of scholarly properties which are set of exclusive right conceded by a sovereign state to a designer or their chosen one for a constrained time frame, in return for open exposure of the innovation. A patent ensures new developments and cover how things function, how they do it, what they are made and what they are produced using. On the off chance that the patent is conceded to the proprietor of development, it gives the proprietor the capacity to make a legitimate move under common law to prevent others from making, utilizing, bringing in or offering the creations without consent.

Figure 2.7 Universal nutcracker tools broken after preliminary test

There are few nutcracker tools found in the market currently but not fabricated in Malaysia. In the next part is some of the nutcracker existed in the market with its review and description of the product.

2.4.1 Prior Art

Prior art is all the information that has been revelation to the general public in any frame around an innovation before a given date. In this undertaking, earlier expressions were done on patent identified with creation of a nut cracker.

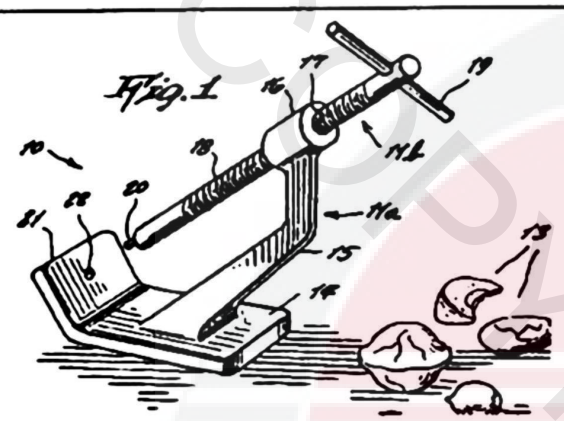
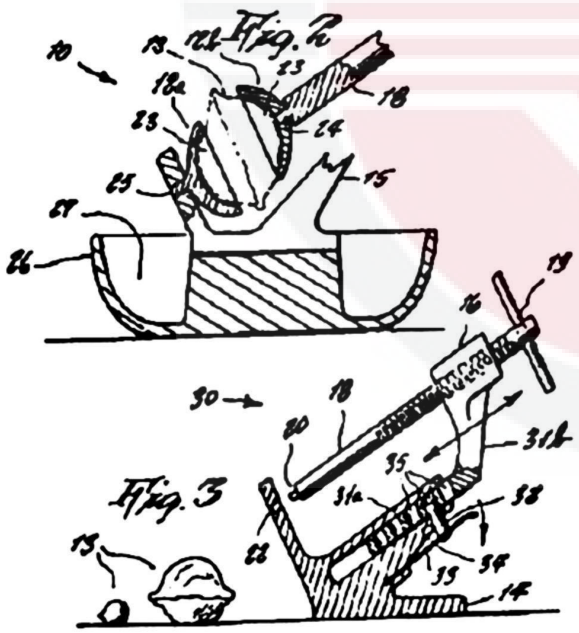
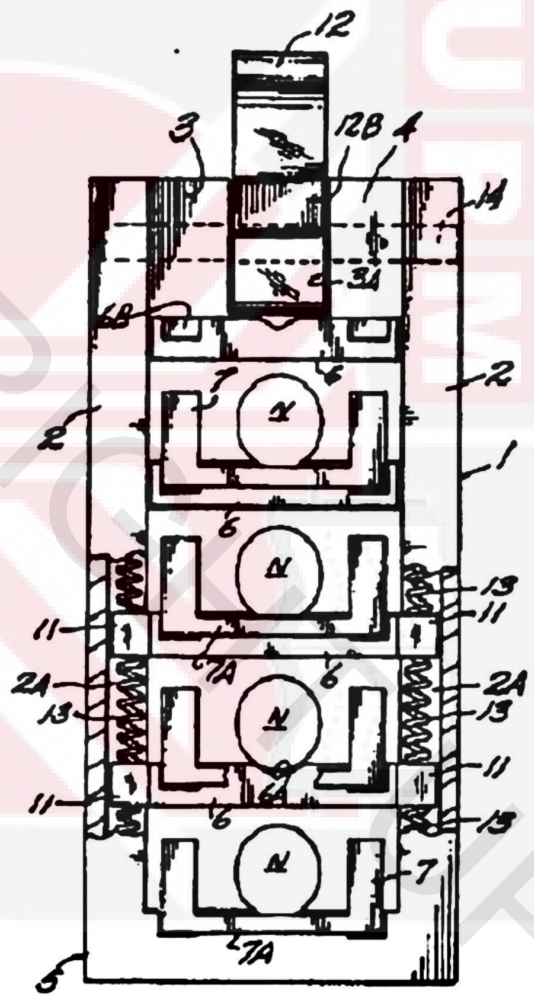
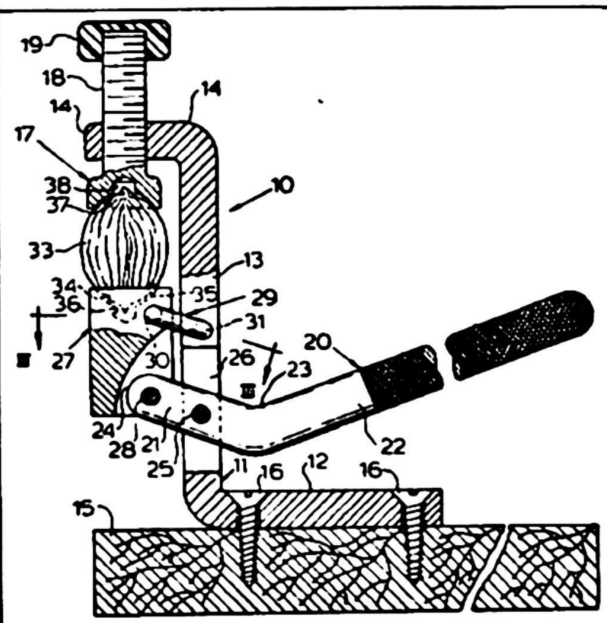
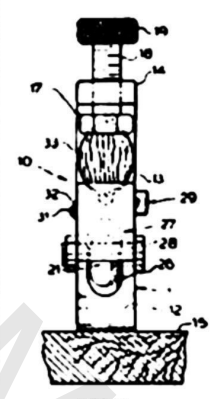
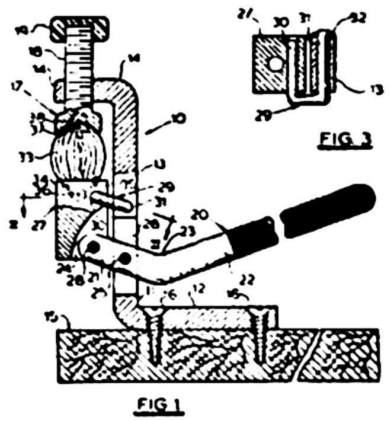
Patent requirements	CURRENT TECHNOLOGY DABAI NUT CRACKER	PRIOR TECHNOLOGY NUT CRACKER (US4077121)	PRIOR TECHNOLOGY NUT CRACKER (US4255855)
Drawing			

Novel process/product	A nutcracker which consists of a top die, which is the main component in this tool, whereas functioning as the cracker when the handle press is push down, the lower part of the top die will descend and cracks the Dabai shell. It is design with a crater shape base just to maintain the vertically position of the nuts during the cracking process. This is important because only when the structure of the Dabai vertically can it only be crack and the kernel inside is not damage or crush. If the nut is cracked or crushed sideways, the separation process of the kernel and the shell would take much time and probably the kernel cannot be extract in full form. The top die is	A nut cracker with a pair of pivotally connected jaws and a pair of handles, each is connected to a respective one of jaws so that opening and closing movement of the handles causes corresponding movement of the jaws. Each jaw has a working face which is disposed in opposed facing relationship to the corresponding face of the other jaw, and the two working faces diverge in the direction of the jaw pivot axis so as to define a wedge shaped crushing space between them. Stop means is to limit the opening and closing movement of the jaws, and resilient means acts between the handles to bias them outwardly and maintain the jaws in an opened position.	A nutcracker which includes a plunger slidable in a stationary sleeve, so that an adjustable end of the plunger is exerted against a nut abutted against a rigid anvil, so as to break open the nut shell, a pivotable handle providing a leverage force against the plunger.

	made from shockproof material (S45) and also is hardened to obtain higher level of hardness. This is important to avoid the top die to easily wear.		
Inventive Step	1. Jig holder with 5 spaces design to hold nuts vertically to ease cracking process. The jig to hold nuts 90 degrees. Comes in 3 different size based on the diameter of the Dabai nuts. The bottom part is design with crater to remain the nut in vertically position to enhance great cracking result. Design with a plastic handle for the user friendly. Made from stainless steel. 2. Double bearing used where	A couple of stretch handles, said handles stretching out for the most part transverse to the rotate hub of said crucial association. A couple of plate-like jaws, each jaw having a wide surface framing a working face which is arranged in contradicted confronting relationship to the comparing working face of the other jaw, and rotate pivot and characterizing a wedge-formed smashing space. Each jaw being stretched for the most part toward said rotate pivot. Each working faces being	A nutcracker, comprising, in combination, a base having a hole through one end thereof, an anvil supported on an opposite end thereof, a space between said ends for placement of a nut therein, a plunger slidable in said holes a pivotable handle for sliding said plunger toward said anvil, and cracking a nut shell of said nut placed between said plunger and said anvil, an adjustable bolt on said plunger for controlling a length of said space, and a reversible bar slide-

	this component is the one pushing the top die downward during cracking process. The use of this bearing is to avoid the friction to the top die as it can cause damage. Made from bearing with high level of hardness and pressure. 3. The press handles acts as the pusher of the top die during cracking process. Design well for the purpose of user friendly. Made from stainless steel. 4. Locking pin system is design when the tools are not in used, the pin can be lock. This is to avoid unnecessary accident	significantly level and being characterized by a majority of converging ribs pockets shaped. Each jaw being associated with a particular one of said handles so development of the handles towards and far from each different. Each jaw having a longitudinal hub. What's more, spring implies acting between said handles and encouraging said handles separated.	fitted in a slot on said anvil, one side of said bar being shaped with a projecting wedge, so as to split said nut shells therewith and an opposite side of said bar having a flat face that is knurled, said reversible bar being selectively positioned with either said wedge or said flat, knurled face toward said nut.

	happen without realizing it and also ease the user when carrying the tool around. 5. The base of the tool as the main holder for the entire component. Made from lightweight hard material (aluminium7075)		
Industry application	For kitchen used / small scale industry	For kitchen used	For kitchen used / small scale industry

Patent requirements	PRIOR TECHNOLOGY NUT CRACKER (US4145962)	PRIOR TECHNOLOGY NUT CRACKER (US4182226)	PRIOR TECHNOLOGY NUT CRACKER (US4377970)
Drawing	 		  

Novel process/product	An implement for breaking open nuts by cracking instead of crushing them. The device includes: i) A concave stationary jaw ii) A concave slidable jaw The stationary jaw is where the nut is seated while the slidable jaw for moving against an opposite side of the nut, the slidable jaw is supported on a screw-threaded shank that rotates in a stationary threaded opening so to advance the movable jaw a specific distance that is enough to crack open only the nut shell and not the nut meat.	A base having a lengthwise extending opening within which are received a number of slidably mounted plate members each spring urged to spaced apart relationship with an adjacent plate member to enable placement of a nut to be cracked thereon. Inserts for each plate member limit closing movement to the plate members. Each plate member is recessed to receive the movement limiting inserts.	A nut cracker includes a base that supports an adjustable fixed anvil member and a moveable ram under the control of a handle, there being a guide interconnecting the ram member in an erect position. The confronting faces of the anvil member and the ram are provided with recesses into which the ends of the nuts are received with clearance so that the outer rim of such recesses engages the nut to provide the cracking force to its shell remotely from the ends of the nut. With this construction, a heavy duty unit is provided which is useful for cracking nuts that have hard/strong shells such as black walnuts and butternuts, and the construction further enables the

			shells to be broken and nut meats recovered in larger pieces.
Inventive Step	A nut saltine involving a stand having a base with a level surface for laying on a level help and a segment essential with said base broadening upwardly and along the side far from said base at a point more noteworthy than 90 degrees in blend with a leg mounted on said base and expanding upward from said base, divided from said parcel, said leg including a strung sleeve having a pivot typical to said partition, additionally including a pivotally mobile jaw having a shank threaded mounted in said sleeve and having a working handle said jaw being dispersed from said base in facilitate mix with a restricting	A nutcracker comprising in combination, a base having a lengthwise orientated opening, a series of spaced apart plate members slidably disposed in said opening to receive a nut thereon, resilient means acting on said plate members urging same to a spaced apart relationship. A lever pivotally attached at one of its ends to the upper end of said base for imparting a nut cracking force to a subjacent plate member and in a sequential manner to each of the remaining plate members and limit means carried by said plate members and limiting closing movement between plate members,	The anvil member and the ram member are each provided with confronting configurations which enable the cracking force to be applied to a nut remotely from its ends. The ram member has a first recess which has a radius of curvature which is less than that of the end of a typical nut so that there is defined a circular rim or edge by which the force is actually transmitted to the nut. In order for the nut cracker to accommodate both black walnuts and butternuts, a second recess of cylindrical form is provided which extends deeper into the member from the bottom of the first recess. The second recess

	settled jaw on said parcel lined up with said hub, additionally incorporating a sadness in said base underneath and enveloping said jaws for accepting separated nut divides, said jaws being removable and replaceable wherein said leg is customizable mounted on said base including a projection parallel to said hub having a space to get said leg and adjusted gaps through said projection and leg adjusted to get a holding pin to secure said leg at different positions in respect to said projection and said partition	said limit means also serving to transfer nut cracking forces from on plate member to another.	accommodates a pointed end of the nut without engaging it so that the cracking force is applied by the rim remotely from the end of the nut no matter what the shape of the end of the nut is. The anvil has a pair of recesses in configuration where it would be omitted if the use of the nut cracker were to be restricted to nuts having non-pointed ends. Also, one recess could be omitted if the use of the nut cracker were to be restricted to nuts having only one pointed end.
Industry application	For kitchen used / small scale industry	For kitchen used / small scale industry	For kitchen used / small scale industry

CHAPTER 3

METHODOLOGY

3.1 Introduction to Methodology

The chronology of the tools 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 existing manual nut cracker for cracking nuts to extract the whole kernel, some considerations and assumptions are being made and carry out through several physico-mechanical testing of the nuts of Dabai fruits to ensure the tools fabrication meet the specification and the objectives of this particular project. The following Figure 3.1 shows the flow diagram of the design process. For the sampling of Dabai nut, the size of the dabai nuts is classified into 2 parts, the bigger size and the smaller size. The justification to the classification of this 2 sizes can be refer to (Azlan, Nadiah, et al., 2009) where bigger size fruits has the mean length, width, and thickness of 4.10 ± 0.11, 2.79 ± 0.13, 0.5 ± 0.00 cm, respectively, whereas the fruit mean length for the smaller size fruits were 3.74 ± 0.08 (length), 2.40 ± 0.07 (width)and 0.4 ± 0.00 (thickness) cm.

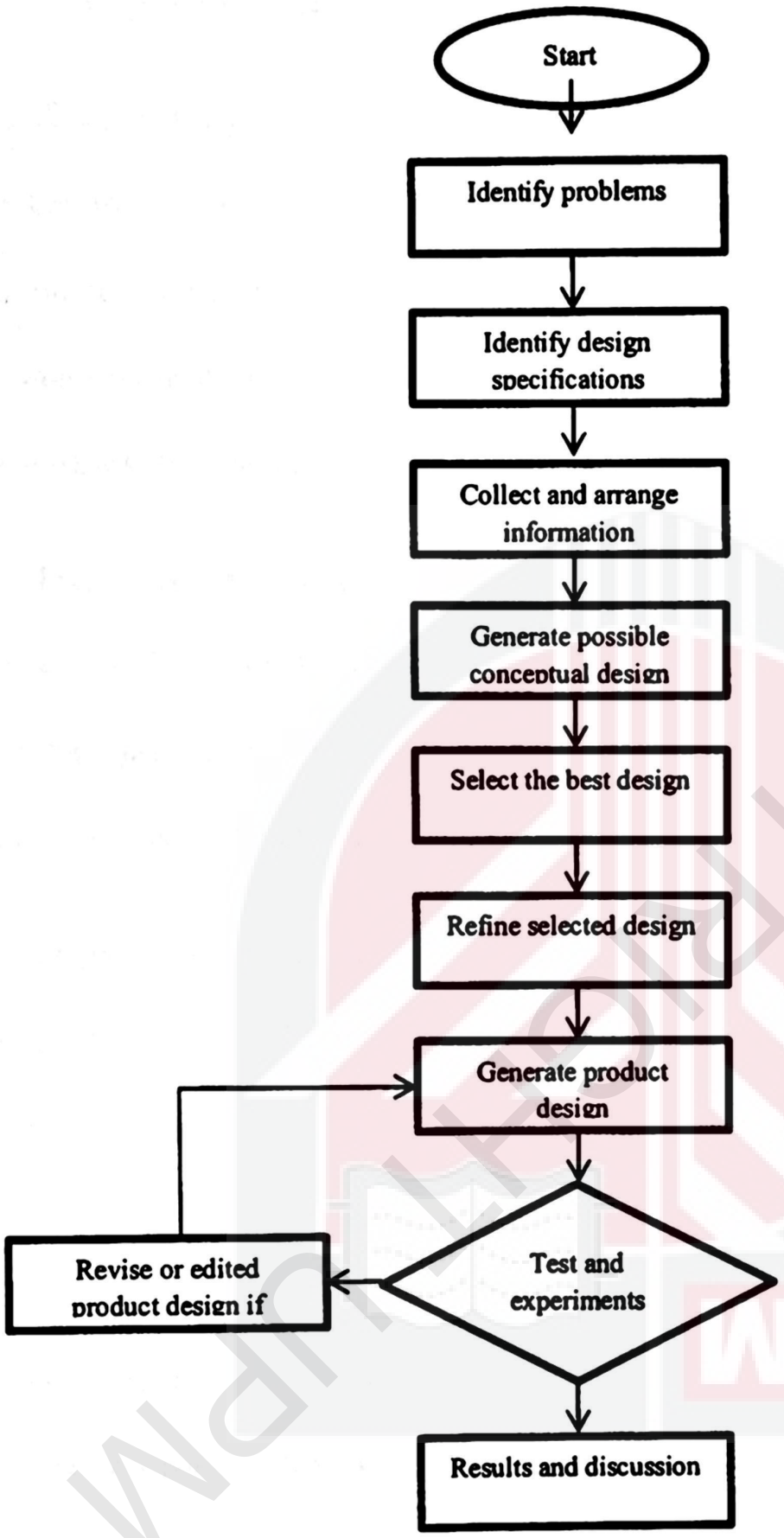


Figure 3.1 Flow diagram of design process

3.2 Conceptual design

The general goal of this examination venture was to outline and create Dabai nutcracker tools that can pop open the nut to acquire the nut kernel for coordinate utilization or other generation purposes. The advancement of these tools was directed in a deliberate request procedure to guarantee the final result is very much acknowledged by the business people and ranchers of Dabai organic products from SMEs.

There are two concepts were developed in considering the need of Dabai Nutcracker tool. These drawing were the first idea drafted on how the tools will be. After evaluating all the parameters involved, the best design is selected for fabrication. The elaborations of the important parts of conceptual design are discussed below.

Objective of the project is to create suitable tools to crack dabai nuts with easy access to its kernel without cause any harm to it. Therefore, in order to achieve this objective, a conceptual design is required to generate ideas for the tools design development. In any projects design or newly projected tasks, the ingenuity of the final product is important features in order to be classified as innovative. These led to an understudy on the previous existing design of the nutcracker tool related to cracking dabai nuts or other similar and most likely to resemble dabai nuts.

In order to create new design, firm knowledge and instruments needed to be polished especially when it comes to draft rough figure to project the draft into proper computer-aided drawing for a more proper form. By drawing more proper illustration of the newly generated design idea, all details and explanation can be included.

3.2.1 Conceptual Design A

Concept design A comprises a handle, a stand connected to the handle, the jig holder, and a base. This design basically resembles the hydraulic press but in much smaller version. The design of the jig to place dabai nuts is also designed according to the nut size. However because of the different size of the nuts, it is not practical to design only one jig holder. Other than that, this design is too simple and does not add much novelty to the design itself. This is one of the criteria been used in this project in order to come out with the best design idea.

Figure 3.2 Concept design A

Figure 3.3 Side View of Concept Design A

3.2.2 Conceptual Design B

Conceptual design B is improved design from concept design A where much more novelty is added to the design. First of all is the jig holder is design with higher number of mould so that it can be compress in a bunch at a time. Other than that, to improve the cracking process, the top die with a hole is design to ease the cracking of the nut. The jig is designed so that the nut is in longitudinal orientation. This is due to the shape of the nuts and after several observation has been made, it is easier to crack open the nuts from this particular orientation. Other than that, it has a double bearing roller to improve the cracking process. When the press handle is pressed down, the roller bearing will in touch with the top die and pushes the top die to moves downwards clamping the nuts in between the bottom die. With the force applied to the press handle is then transferred to the top die and the nuts is cracked open.

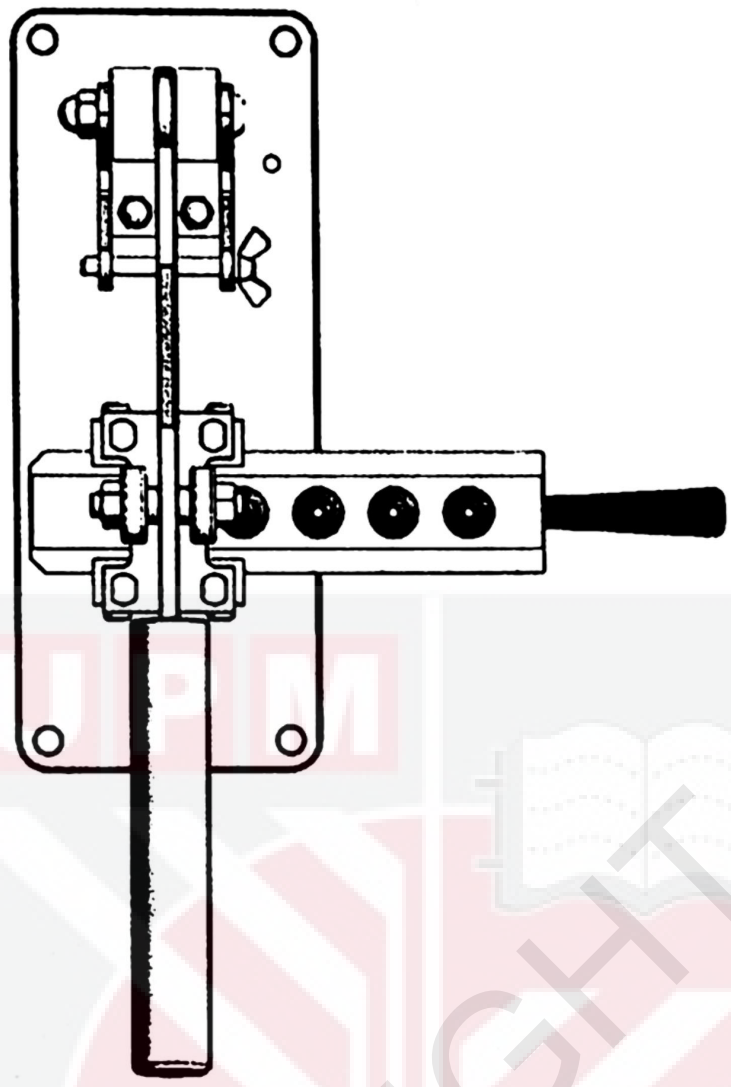


Figure 3.4 Top View of Concept Design B

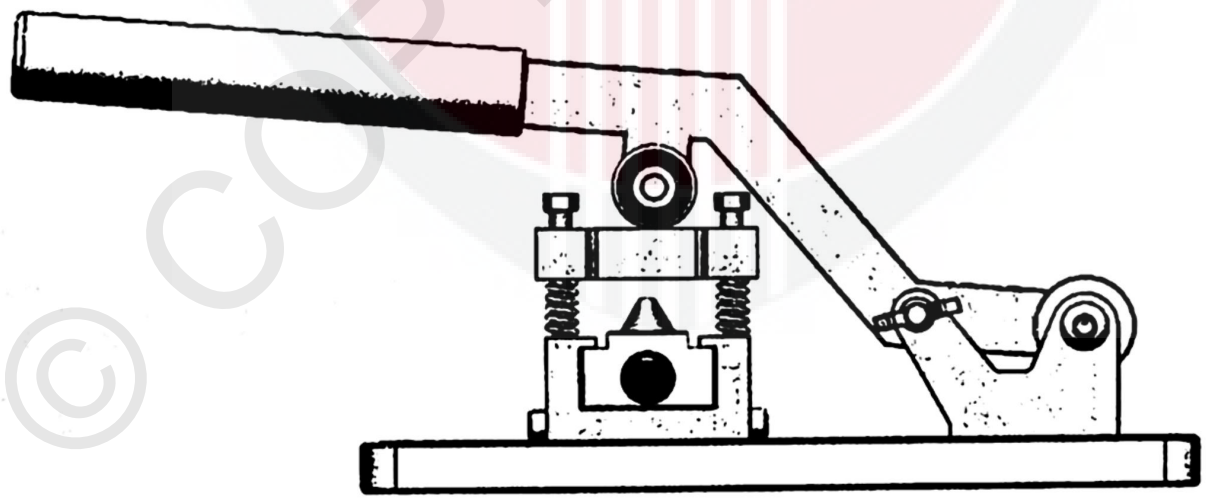


Figure 3.5 Side View of Concept Design B

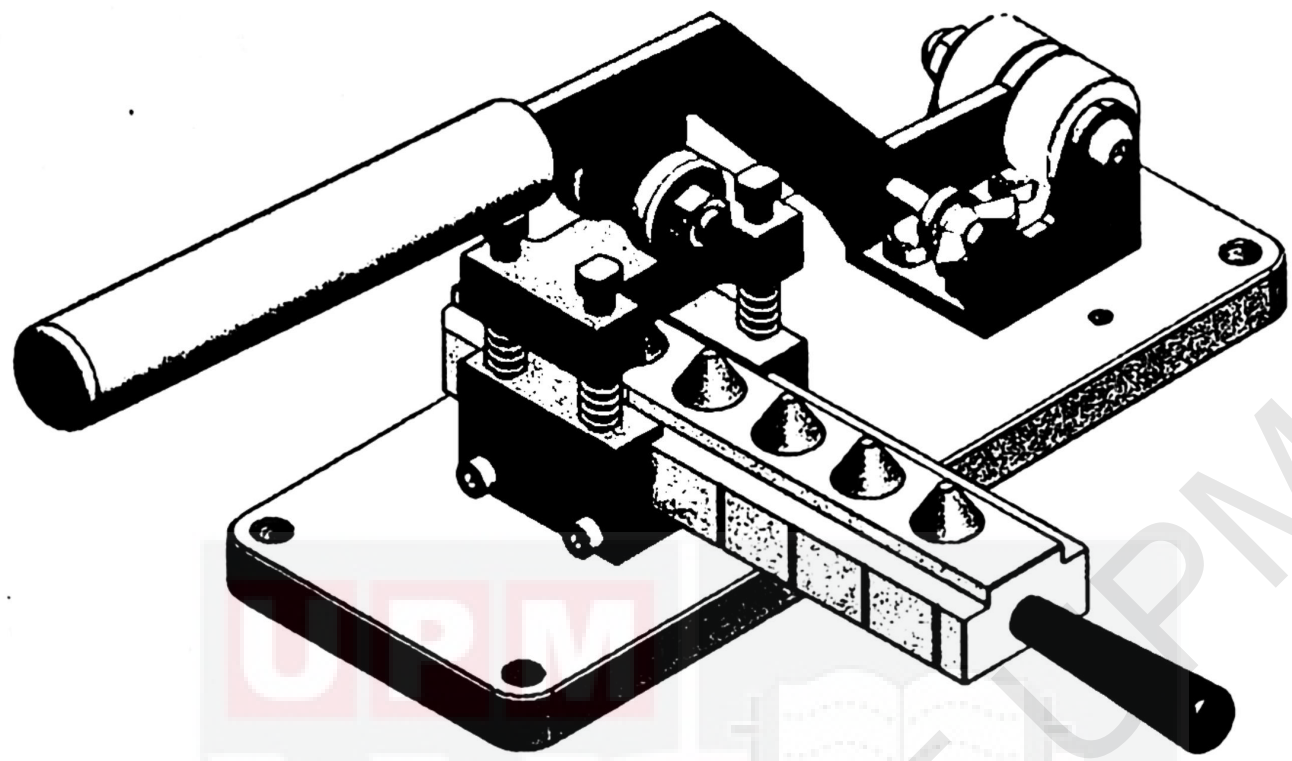


Figure 3.6 Front View of Concept Design B

3.3 Conceptual evaluation and selection

From the ideas of illustrations that were created in outlining the Dabai Nutcracker tool, the best plan should be chosen. Along these lines, organized strategy for idea determination is directed. There are two phases of calculated determination which is the primary stage is to dispose of the idea thought produced from many to a relative couple of that will get extra refinement. At second stage, the rest of the idea configuration is assessed to choose last idea plan. Some choice criteria and the depiction utilized for idea screening and idea scoring are appeared in Table 3.1

Table 3.1 Description of the Criteria Used in Conceptual Evaluation

Criteria	Description
Security	The tools must be safe to be handled by operator.
Efficiency	The capacity of the tools should be better than manual method.
Preservation	Parts of the tools can be reached or detached easily for cleaning purpose.
Convenient	The tools should be convenient to use especially aspect of operation handling.
Functional design	The tools should consider of the most comfortable positions when handling the tools.
Capacity	The size of the tools aims to be lightweight, compact and easy to transport.
Economical	Material cost, manufacturing cost and assemble cost must be affordable for the targeted customer.

3.4 Method Selection of the Tools Design

Pugh Concept Selection method is one of the way to be applied in order choose the best concept design idea. This method is a type of matrix diagram that allows for the comparison of a number of design candidates leading ultimately to which best meets a set of criteria. It also permits a degree of qualitative optimization of the alternative concepts through the generation of hybrid candidates (Burge, 2009). A lot of decision making often concern a number of criteria to be met for which human being are unable to decide or to handle the complexity resulting in inconsistent and irrational decisions. Table below shows the Pugh Method Process flow chart.

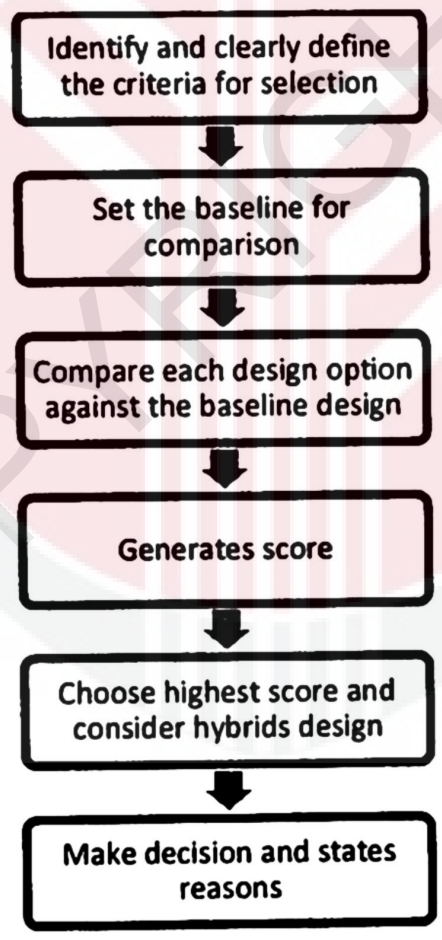


Figure 3.7 Steps to construct decision-matrix (Burge, 2009)

Table 3.2 Details of every steps in constructing decision matrix (Burge, 2009)

Step	Explanation
• Identify and clearly define the criteria for selection	Identify and clearly define the criteria for selection. Typically when using a Pugh Matrix to select between a number of candidate design options the design requirements can be used either in part or in whole. Ideally the design requirements should reflect both the user-customer as well as other key stakeholders including internal stakeholders. The robustness and validity of the outcome is fundamentally dependent on an appropriate set of criteria/requirements. Rushing this step usually results in a non-robust outcome that is challenged and overturned.
• Set the baseline for comparison	Use one candidate design option as the baseline and core all criteria/requirements as "S" (some people prefer to use an O) for this baseline. If appropriate, a good choice is to, use the previous design for the baseline because it exists and therefore its performance should be reasonably well known.
• Compare each design option against the baseline design	Compare each candidate design option against the baseline design, criteria by criteria (or requirement by requirement) and decide a "pair-wise score with: S = same + = better - = worse It is also possible to add extra

	levels of discrimination by using: ++ = much better -- = much worse Some people use a 1 to 5 scale where the baseline/same is a 3 with 1 and 2 being much worse and worse respectively, and 4 and 5 being better and much better respectively
• Generates score	For each candidate design option the total score can be calculated by summing the number of (+), (–) and (=). The highest ranked score is the 'winner' but use common sense – don't just select 'highest' ranked concept.
• Choose highest score and consider hybrids design	Having scored each candidate design option consider hybrids by combining where possible the best from each alternative. This is form of qualitative optimization.
• Make decision and states reasons	Make the decision and record reasons behind decisions. Quite often with a Pugh Matrix there is no clear 'winner' but there is often a clear 'loser' in such cases perform a sanity check (does the decision make sense) and remove the losing option. At this point the criteria/requirements can be weighted to give better differentiation. Typically the weighting is on a 1 to 5 scale with 1 the lowest and 5 the highest weighting. If there is still no clear winner, the matrix is basically saying that there is not enough information to discriminate between the options.

3.5 Design Process

Design process is usually starts with the clarification of the needs and chances and ended with the presentation of the plans which will satisfy the needs. The systematic approaches were carried out for synthesis of the components inclusive of design calculations, detailed drawings, assembly drawings, cut away view and the view of completed tools. Figure 3.8 illustrate the complete flow of work diagram of this project.

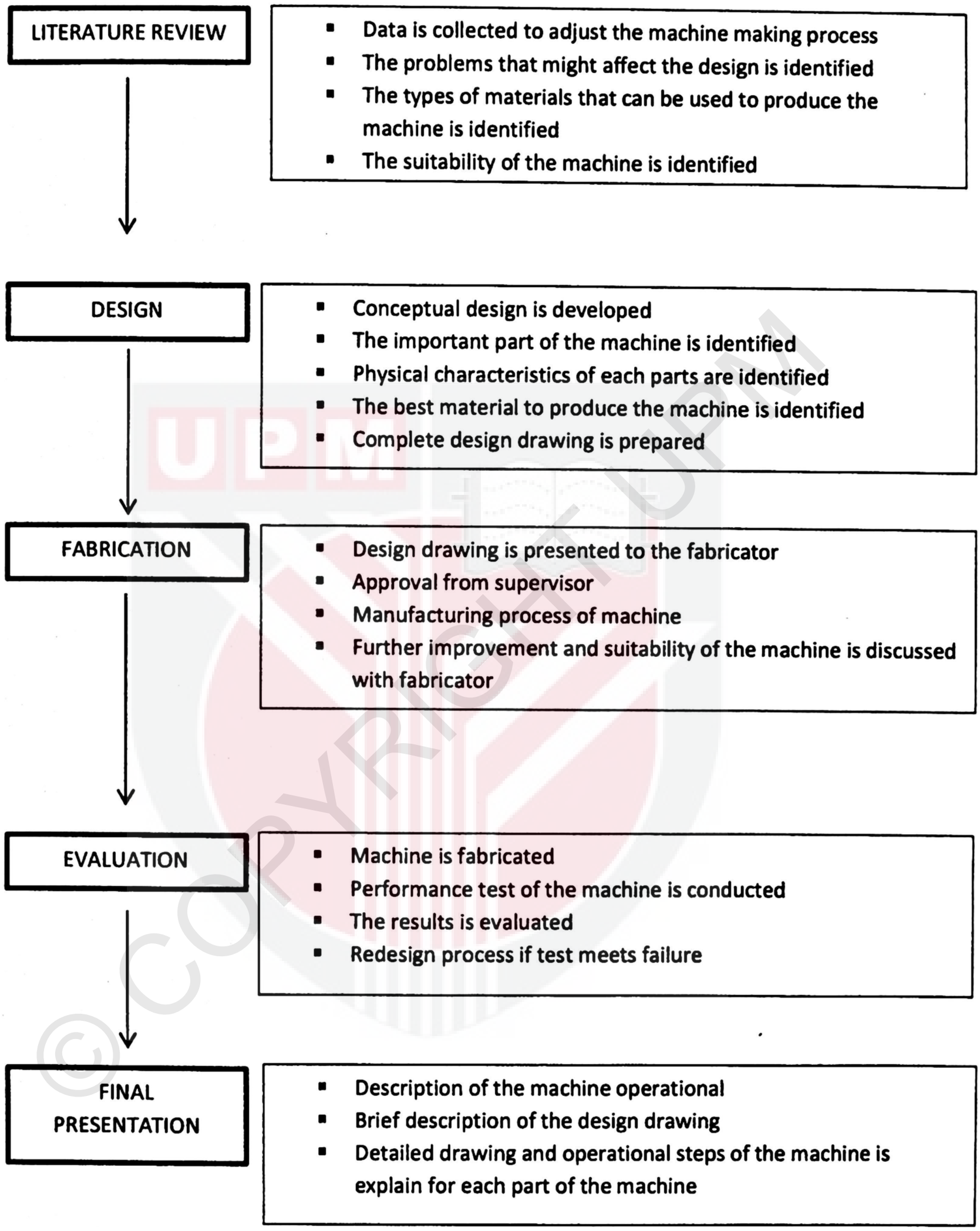


Figure 3.8 Flow Work of the Proposed Process Design

3.6 Parameters in Designing tools

The dabai nut is collected from the Health and Medicine Faculty where an ongoing research is being done on the flesh of the dabai fruits. The physical properties of the nuts that were considered in this study included the axial dimensions, weight, geometric mean diameter and spherecity of the nuts. The dimensions need to be measured to obtain the average, maximum and minimum size of the nuts. This parameter is important to design the size of the holder of the nuts use to load the nuts before cracking.

Table 3.3 Compressive Load at Break Point (Longitudinal axis)

Compressive load at break (N)	Bigger nut	Smaller nut
Sample 1	13.70	85.68
Sample 2	44.88	113.03
Sample 3	201.24	394.22
Sample 4	239.69	275.18
Sample 5	106.33	78.35

Table 3.4 Compressive Load at Break Point (Transverse Axis)

Compressive load at break (N)	Bigger nut	Smaller nut
Sample 1	209.96	168.58
Sample 2	121.17	71.87
Sample 3	301.79	161.60
Sample 4	46.54	39.76
Sample 5	68.52	64.81

The nuts were first dried in a laboratory oven at 50°C for 10 h. This temperature was chosen in an attempt to simulate the closest conditions to sun drying. All the weights of initial and final of each replicate are recorded to ease the process of determining the moisture content express in %. The dimensions of each replicate is

recorded at the beginning of the experiment shows almost similar size before and after oven dried. This shows that, although drying may affect the size of the nuts, however it is not a major problem as the size is not reduce drastically, furthermore not going to affect so much on the design of the nutcracker tools holder. All the data obtained is tabulated in. All measurements taken are using lab-scale instrument and in the case of measuring weights, the electronic balance and for the dimensions by using simple ruler and vernier caliper. From Table 3.3 and 3.4 above shows that, un-uniformed pattern of force needed to break the nuts on both longitudinal and transverse axis. This may cause by the maturity of the nuts because the nuts obtained has been kept for several months inside a freezer and might have been mix around with new and old harvested nuts.

However, the most suitable axis to break the nuts and access the whole kernel without crushing it is by using the longitudinal axis where in Figure 3.9 below shows the kernel obtain from the experiment conducted where shows clear evidence of the statement above. These results will helps a lot especially when developing and fabricating the cracker for dabai nut in order to access the whole kernel.

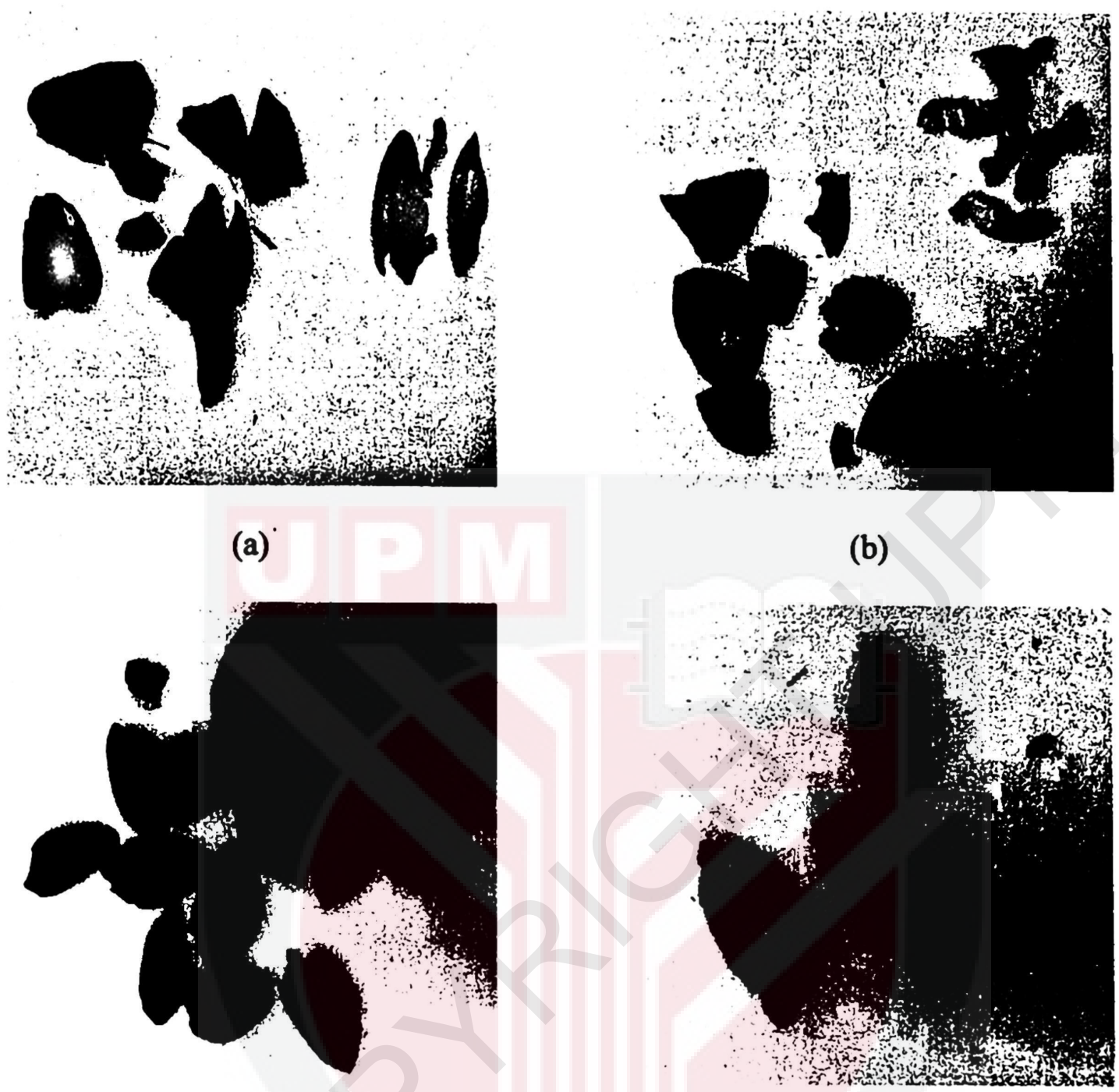


Figure 3.9 (a) nut with kernel compressed transversely, (b) nut with kernel compressed transversely, (c) kernels from nuts compressed longitudinally, (d) nut and kernel compressed longitudinally

3.6.1 Determination of Physical Properties of Dabai Nut

Physical and mechanical properties of *Canarium odontophyllum* are crucial parameters in building up the outline idea of the Dabai Nutcracker tool. Physical properties such as size and shape, mass, and mechanical properties such as compression strength rupture force need to be measured in the early stages in inventing the tools. However there are not plenty enough studies has been carried out about the determination of the nuts of *Canarium odontophyllum.*

The physical properties of the nuts that were considered in this study included the axial dimensions, weight, geometric mean diameter and spherecity of the nuts. The size of the dabai nut was expressed in terms of its length, width, and height. Since the transverse cross-section of the nut is almost triangular, the width may be difficult to determine from all the sides of the nuts. Therefore, measurements were done when the widest and bigger side of the nut was facing the surface.

i) Size of Dabai Nut

For each nut, three linear dimensions were measured, that are length (cm), width (cm), and thickness (cm) using a standard metal ruler and a vernier caliper reading to 0.01 cm.

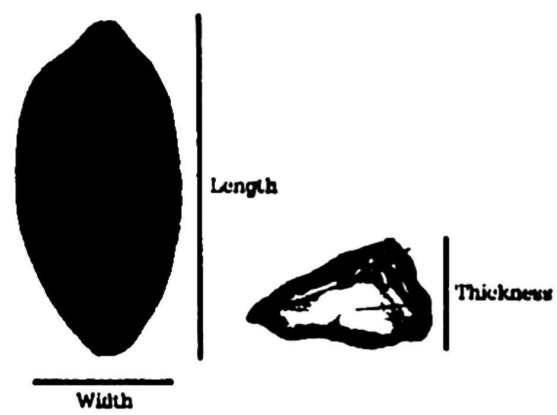


Figure 3.10 Dimensioning of typical dabai nut

ii) Weight of Dabai Nut

The mass of each nut for small and big sizes of nuts is determined by using an electronic balance reading to 0.0001 g. The mass for each sized is presented as an average value.

iii) Geometric Mean Diameter

For geometric mean diameter, (Aydin, 2003) suggested following Mohsenin (1986) using the equations for geometric mean diameter as follows:

$$D_m = (LWT)^{1/3} \quad (1)$$

Where D_m the geometric mean diameter of the nut, L is the length of the nut, W is the width of the nut, and T is the thickness of the nut.

iv) Moisture Content & Moisture remove

Because of the pretreatment suggested, by drying the nut under the circumstances stated, certain amount of the moisture will be removed from the nut and it will become dry. Cracking and breaking process will be much easier because the nut can give higher yield.

$$\%\ Moisture\ Removed = \frac{Initial\ weight - Final\ weight}{Initial\ weight}\ x\ 100\% \quad (2)$$

moisture content remove from the nut can be calculated using formula suggested by (Gallegos, Suministrado, Amongo, & Madlangbayan, 2013) as follows:

$$MC_{nut} = \left[\frac{\left(w_i^k - w_f^k\right) + \left(w_i^s - w_f^s\right)}{\left(w_i^k + w_i^s\right)}\right] x\ 100 \quad (3)$$

The initial weight of the nut before drying and the final weight of the nut after drying process are measured to calculate the percentage of moisture removed from the drying process of which implicates or similar to 3 days of sun drying.

v) True Density & Bulk Density

The bulk density is determined by the ratio of the mass of a sample of the nuts to its total volume (Aydin, 2003) and the true density is determined by the ratio of the mass of a sample of a nut to the solid volume occupied by the sample. The nut volume and their true density were determined using the liquid displacement method (Aydin, 2003). In this case the liquid used is water. However it has a tendency to be absorb by the nuts therefore immediate measurement and readings need to be taken after the nuts is placed inside the container or cylinder used.

$$\text{True Density, } \rho T = \frac{mass\ nut}{volume\ water\ displaced} \quad (4)$$

$$\text{Bulk Density, } \rho = \frac{mass\ of\ samples\ of\ seed}{total\ volume} \quad (5)$$

vi) Sphericity and Aspect Ratio Of Dabai Nut

The nut shape was expressed in terms of its sphericity index and aspect ratio. For the sphericity index S, the dimensions obtained in size above were used to calculate the value based on the equation as follows: (Azlan, Nasir, et al., 2009)

$$S = \frac{(LWT)^{1/3}}{L} \times 100 \quad (6)$$

Where L is length (cm), W is width (cm) and T is thickness/height (cm). The aspect ratio R was calculated as recommended:

$$R = \frac{W}{L} \times 100 \quad (7)$$

All data for sphericity and aspect ratio is stated in percentage (%).

3.6.2 Determination of Mechanical Properties of Dabai Nut

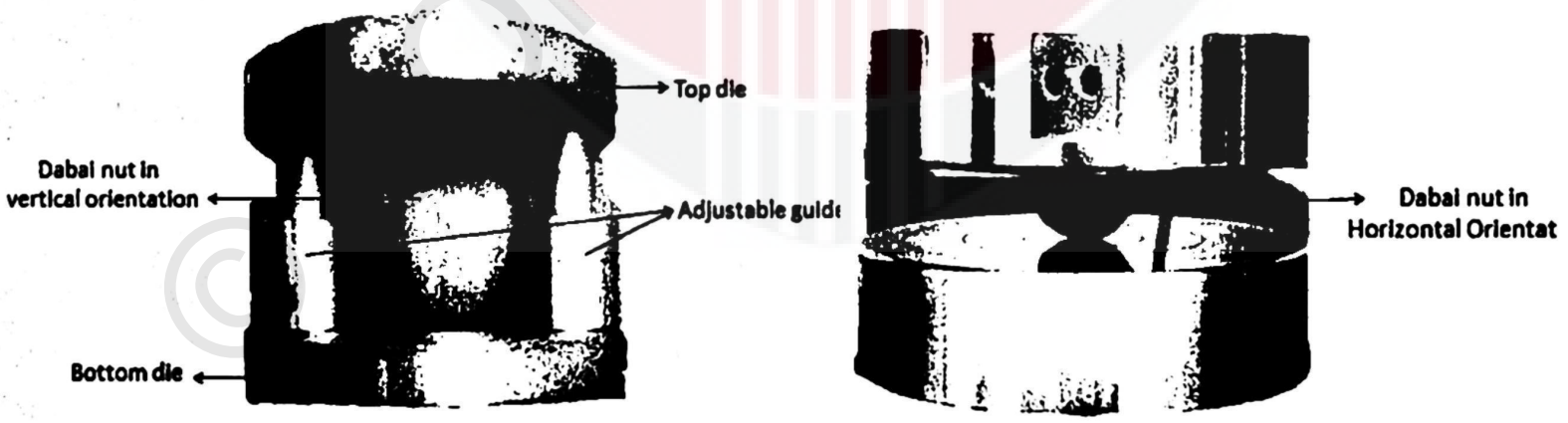
The mechanical properties of the nuts were carried out through analysis of the compressive failure characteristics of the nuts. The cracked patterns of the nuts were examined thoroughly and taken picture for presentation. The quality of the kernel after compression also is examined for any damage. The amount of damaged kernels was reported as a percentage of the total number of nuts compressed.

The compressive load/force needed to break the shell and its corresponding deformation was determined using a Universal Instron Testing Machine Brand (Model 8500). The loading capacity is set to read at a 10 kN for a better results. Depending on the shape orientation of dabai nut, two compressive loading orientation is applied which is transverse and longitudinal orientation. The compression test was based on ASAE standard – Compression test of food materials of convex shape (ASAE Standard, 1998). To reduce human errors or mistakes, the Instron was set to auto-mode during the runs. A 4 mm min^{-1} compression speed is satisfactory to carry out the compression test. For each size and compression orientation, five nuts were selected and compressed.

There are two ways for nuts to be cracked. Firstly by putting the nut vertically and compressing it from the side of the nut. Secondly, by compressing the nut in horizontal orientation where the nut basically stands on its tip. Cracked pattern of both ways also has been observed previously to have major effect on the kernel inside the shell of the nut. Nuts compressed vertically causes major damage while nuts compressed

horizontally give better results of the kernel. This is due to the side of the nut is more breakable compared to the tip of the nut. Even with constant force applied to both ways of compressing. Other that, because the nut is shape like a triangle having three rut on its tip, therefore it is easier to cracked open the nut horizontally as all three shell parts of the nut will come off easily without damaging the kernel inside.

The compressing along the longitudinal direction faced difficulty in maintaining its orientation and that is due to the fabrication of a compression jig. The fabrication of dabai compression jig is purposely designed to help in maintaining the orientation of dabai nut during compression process by Instron Machine (refer Figure 3.11). The component of the compression jig comprises of a top die with a crater hole in the middle of the die, bottom die with a crater hole in the middle of the die, and pair of adjustable guide dies to connect between the top and bottom die. When the nut is loaded to the jig, due to the round crater hole on the dies, the nut will be able to stands on its own without moving when it is compressed.



(a) (b)

Figure 3.11 Compressive force applications along the longitudinal (a) and the transverse (b) axes of dabai nut

The advantages of determining the mechanical properties of dabai nut in the preliminary phase are to get or obtained the most suitable form of the nut to be cracked open. Other than that it is compulsory especially when it comes to developing the design concept of the dabai nut cracker. For the time being, there is only several research have been made regarding the determination of physical and mechanical properties of *Canarium odontophyllum,* therefore the closest and most similar published paper that has been used as referral when conducting the this preliminary phase is from (Gallegos *et al.*, 2013) which indicates the physical and mechanical properties of pili fruits and nuts *Canarium Ovatum*.

The force and corresponding deformation required to break the shell is highly important parameters in developing the concept design of the nut cracker because they dictate the sizes and the correct orientation and configurations of the tools and ease the components of the tools to be made and assemble. As shown in Figure 3.12 is the figure of dabai nut that has been compressed longitudinally which is compressed while it is in standing on its tip position, while Figure 3.13 is the figure of dabai nut compressed transversely which means it is compressed when the nut is laid down on its side.

Figure 3.12 Dabai Nut Compressed Horizontally

Figure 3.13 Dabai Nut Compressed Vertically

3.7 Construction and Structure of Dabai Nutcracker

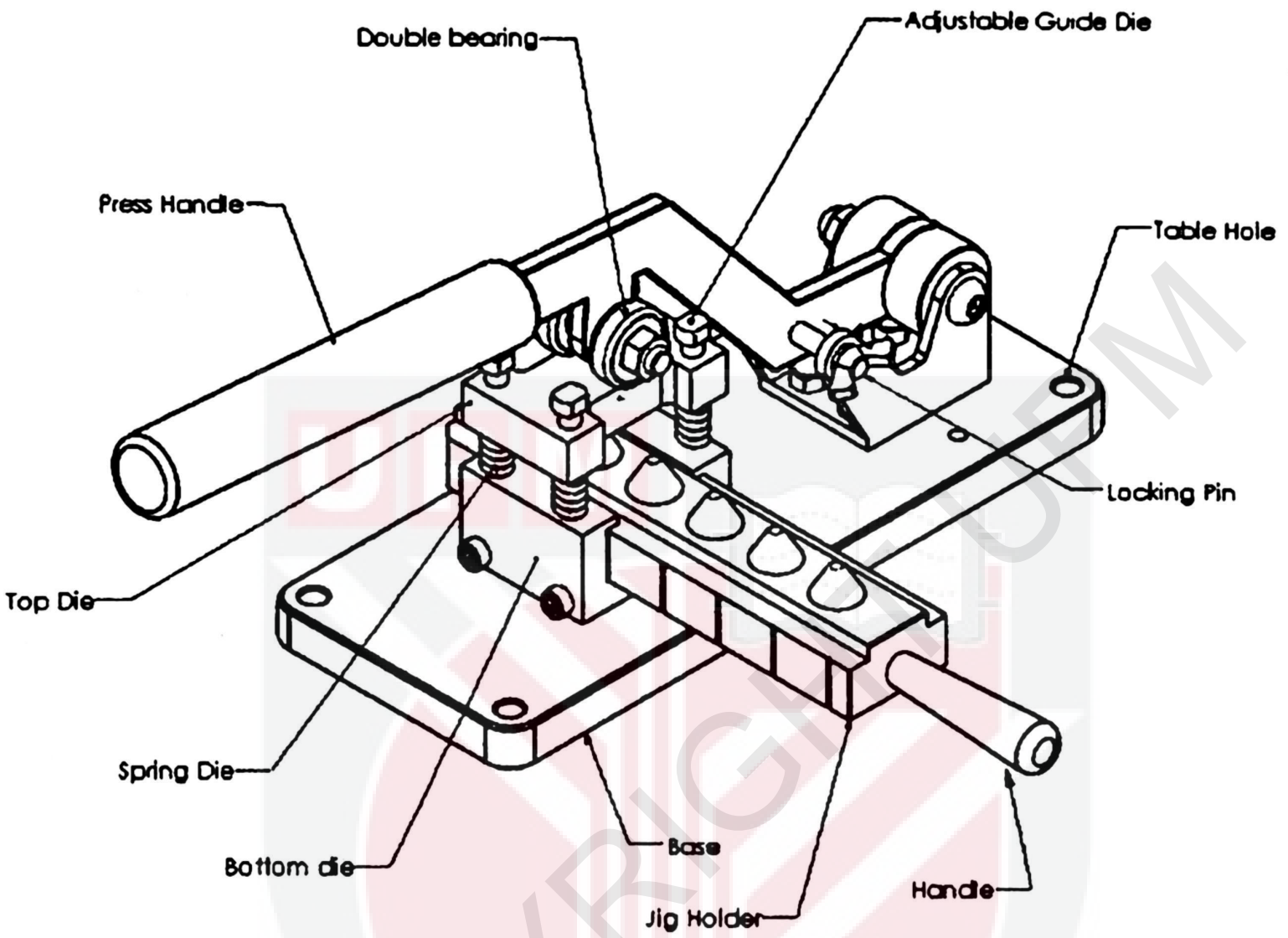


Figure 3.14 Components in Dabai Nutcracker

Figure 3.14 shows the Dabai Nutcracker that had been developed by using SOLIDWORKS software. The main components of the invention are the press handle, top die, adjustable guide die, spring die, bottom die, the base, jig holder, jig holder handle, locking pin, table hole, press handle bracket, and double bearing. The detailed of design drawings are shown in Appendix A1 to A10.

3.7.1 Press Handle

It is a major component of the operation of this tool, acting as a top die suppressor during the dabai skin breakdown process. It is made with an easy-to-handle, handle. The material of the handle is made from stainless steel and pressure-resistant.

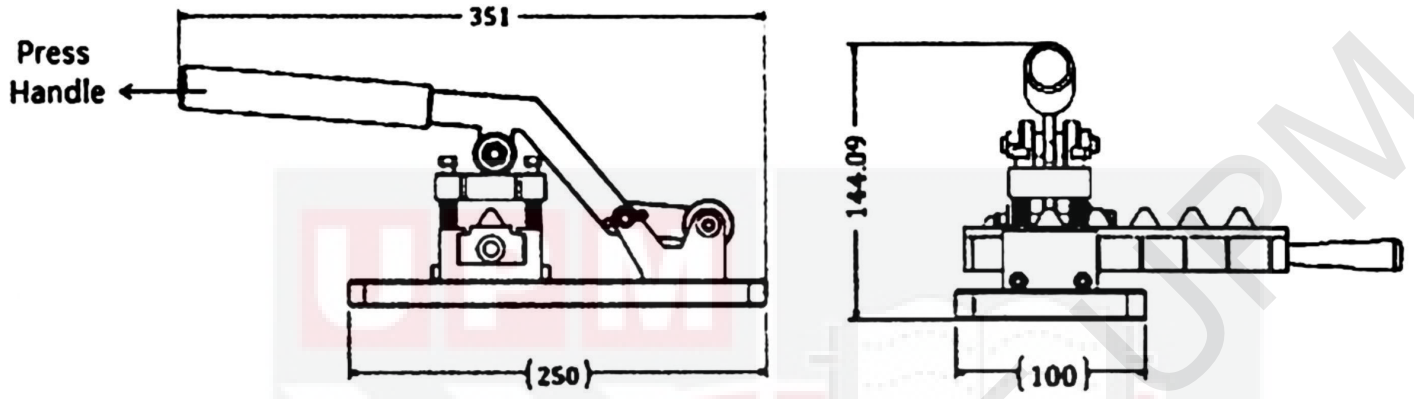


Figure 3.15 Schematic Diagram of Top Die

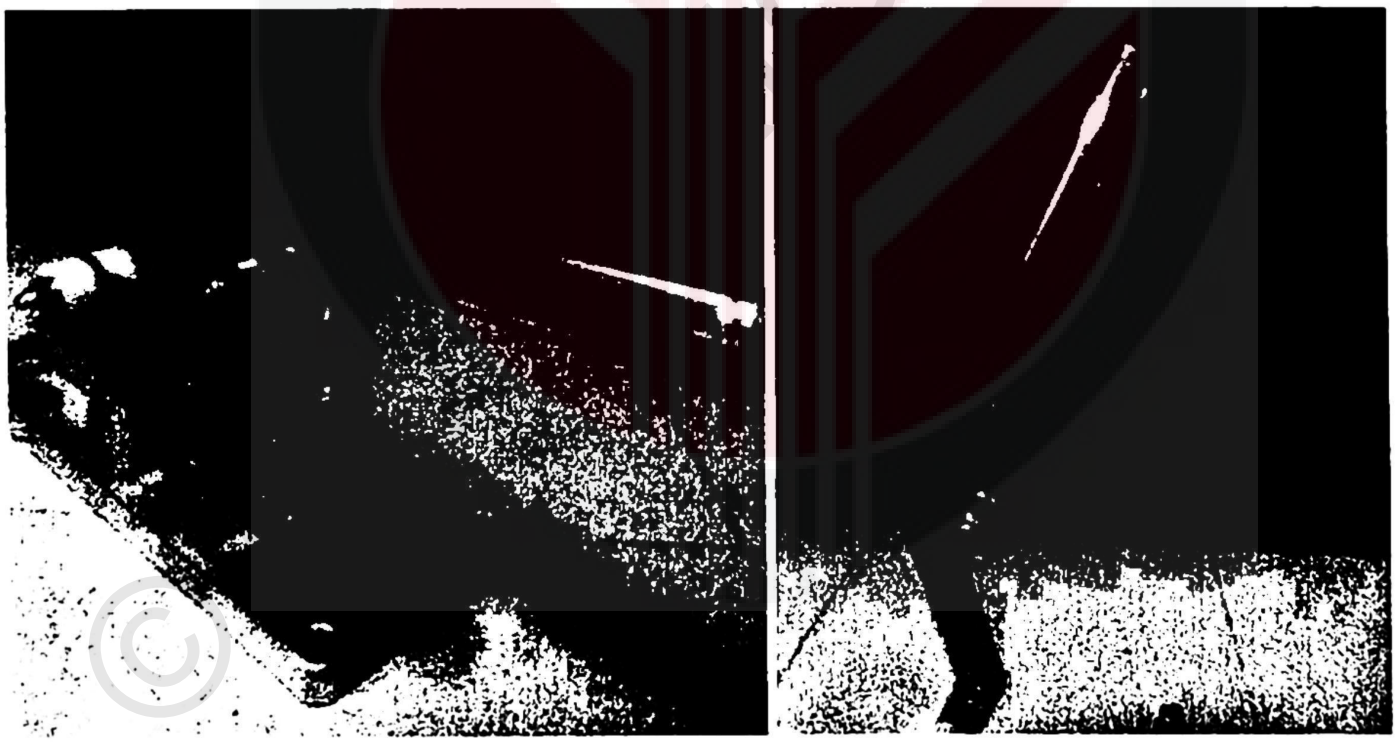


Figure 3.16 The Press Handle of Dabai Nutcracker

3.7.2 Top Die

It is the main component in this tool, which acts as a skin breaker when the press handle is pressed, the bottom of this top die will decline and break the dabai skin. It is designed to be shaped like crater to maintain the position of dabai nut during the process of cracking. It is very important because with only the structured vertically only retained the shape of the kernel fracture from broken or damaged. If the dabai content is broken or damaged, the isolation process will take a long time and the possibility of dabai content can no longer be used. This die screen is made of resistant material (S45) and made hardening to obtain higher hardness. This is important for avoidance of rapid damage to the top die. All the dimensions for top die can be seen in Figure 3.17 as follows.

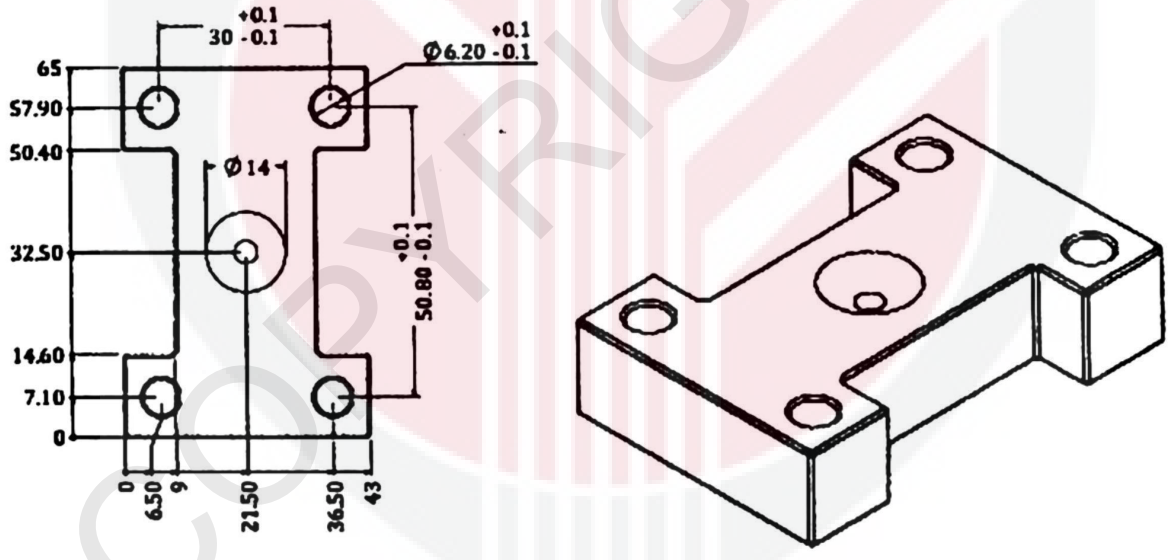


Figure 3.17 Schematic Diagram of Top Die

Figure 3.18 The Top Die of Dabai Nutcracker

3.7.3 Spring Die

The function of spring die is to repel the top die and make the top die returns to its original position after the cracking process is done. This part is made of flexible and stainless steel (spring steel).

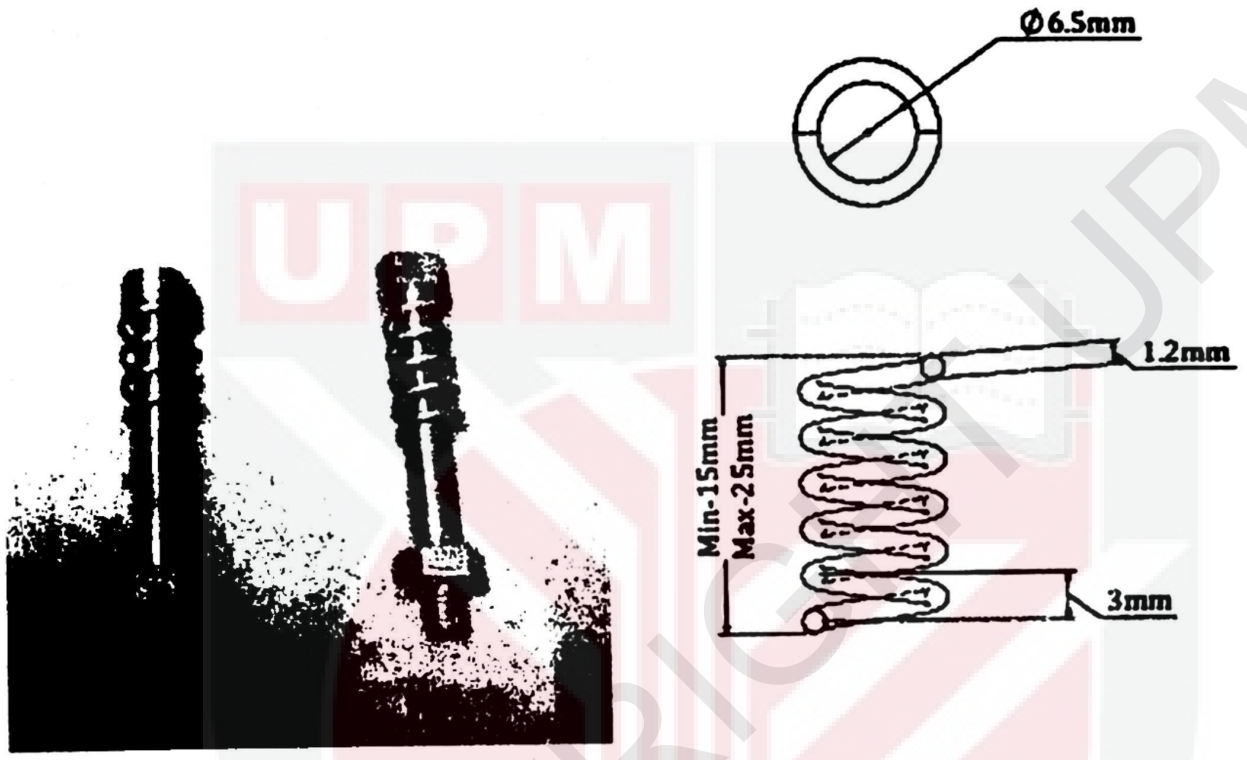


Figure 3.19 The Spring dies of Dabai Nutcracker

3.7.4 Adjustable Guide Die

This part holds between top die, bottom die and spring die section. It is very important during the operation of this tool as this adjustable guide plays an important role as the rail for the top die to runs smoothly and accurately. It is also designed to be adjusted in terms of its height so that the top die can follow the size of the dabai nut height. This part is mainly made of stainless steel with high hardness. There two piece of this part. Dimensions of this part are included in Figure 3.20 as follows.

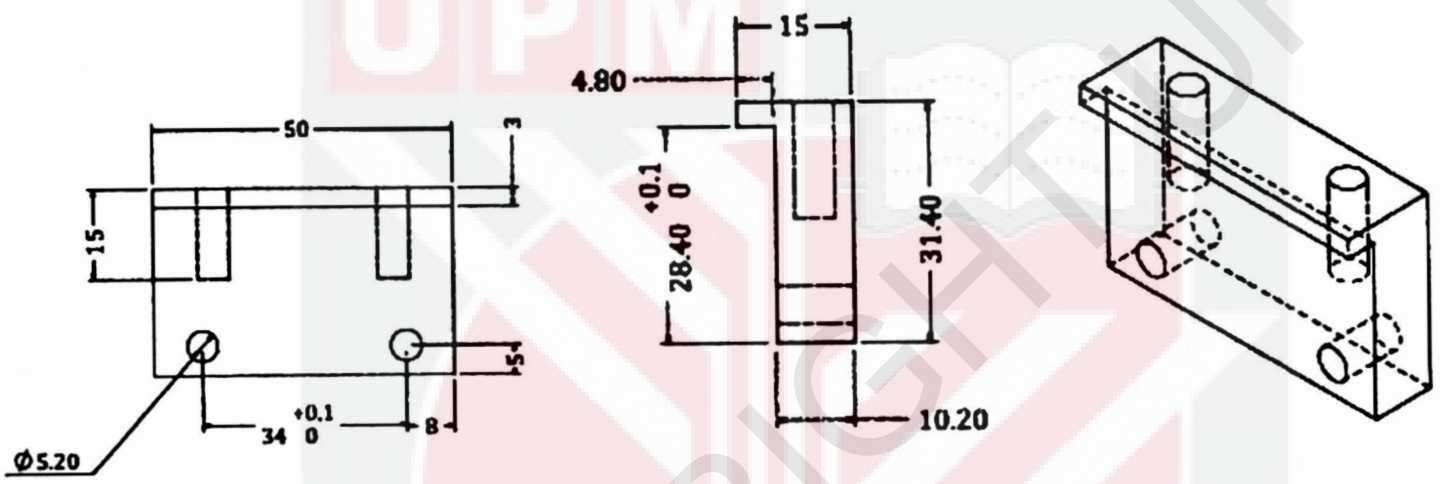


Figure 3.20 Schematic Diagram of Adjustable Guide Die

Figure 3.21 The Adjustable Guide die of Dabai Nutcracker

3.7.5 Bottom Die

This part favors as the route for the jig holder to moves towards the top die exactly and accurately when the press handles is being pushed during the process of cracking. This part is made of stainless steel with high hardness. This part has the dimension 50 mm (length) x 40.40 mm (width) x 10 mm (height).

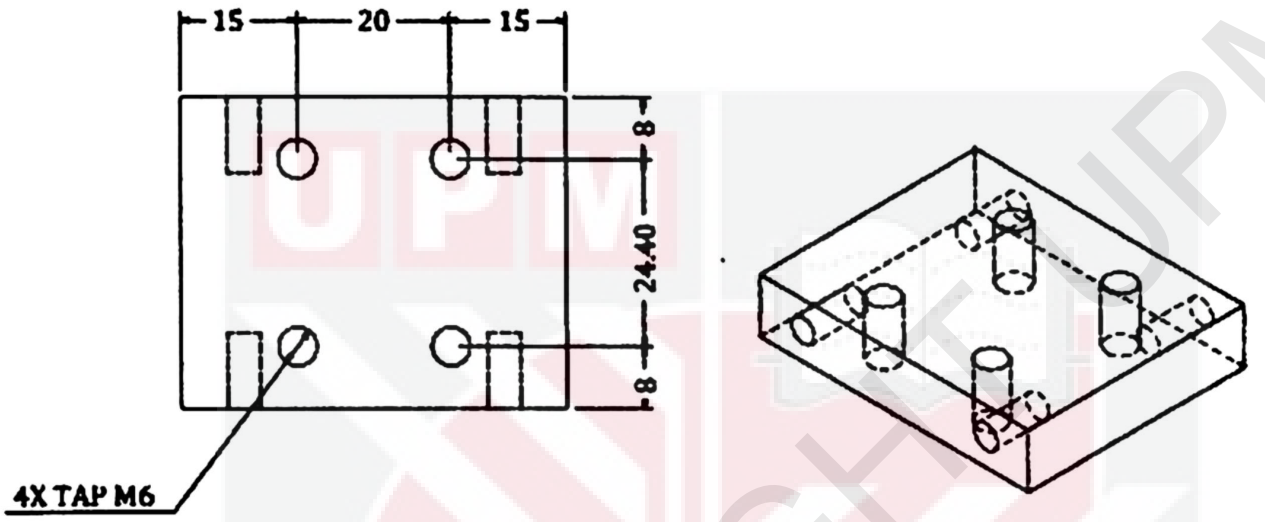


Figure 3.22 Schematic Diagram of Bottom Die of Dabai Nutcracker

Figure 3.23 Bottom Die of Dabai Nutcracker

3.7.6 Jig Holder

Jig holder serves as a stand-alone to position the dabai nut at vertically position (90 degrees) it has to be compress at 90 degrees so that it cracks open along the rut of the nut which makes it easier to retrieve the kernel without causing damage to the kernel. It is made up of five spaces for placing the dabai nut at one time, and comes in three different sizes according to the size of the dabai fruit. The lower part of the holder is also designed in the form of crater shape. It is very important to make sure the position of dabai nut is in straight and vertical position so that the shell breaks even during the cracking process. This part is also designed with a plastic handle holder to facilitate the user during the process. This part is made of stainless steel and has high hardness. The dimensions of this part are mention in Figure 3.24 below.

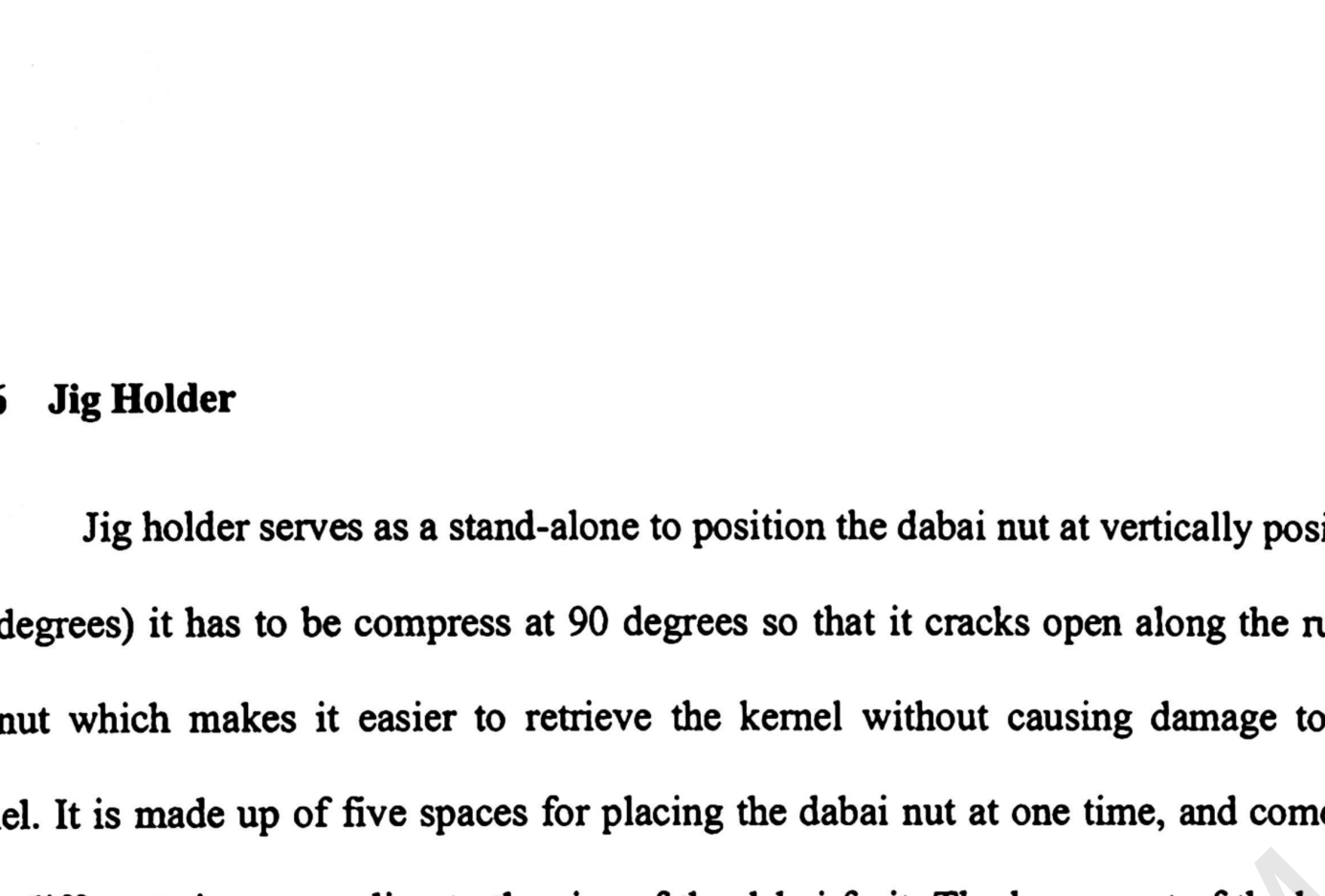


Figure 3.24 Schematic Diagram of Jig Holder

3.7.7 Double Bearing

This bearing is in touch and pressing the component of top die during pressing of the press handle and the cracking process. When the double bearing touches the top die, the bearing will move slightly to the center of the middle die to get the exact pressure. The use of this bearing is to avoid friction on the top die and damage it. This bearing is made from steel bearing and has highly resistant to hardness and pressure. All the dimension of this part is included in Figure 3.25

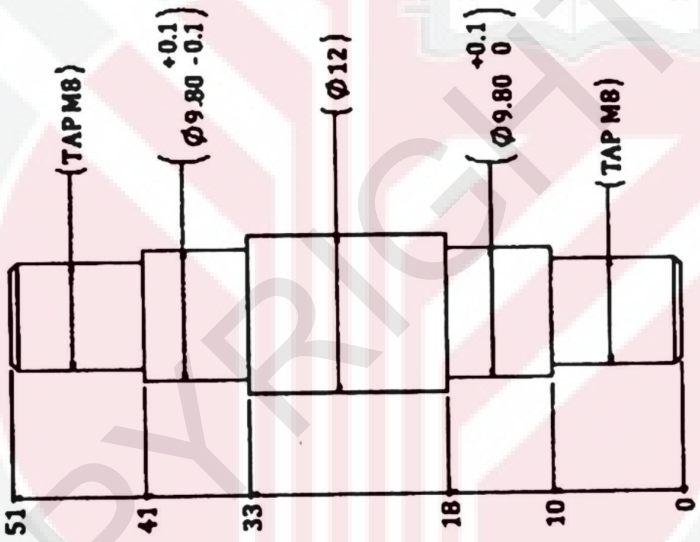


Figure 3.25 Schematic Diagram of Double Bearing

Figure 3.26 Double Bearing of Dabai Nutcracker

3.7.8 Locking Pin

Locking pin is the key to lock the press handle with top die. When the locking pin is installed, all the operation of this tool will not be possible. Besides that the locking pin is also designed for the purpose of user safety for the users to carry the tools anywhere. Dimensions of this part are included in Figure 3.27. The user can also simply lift the tool by simply holding the press handle. This part is made of stainless steel and has high hardness.

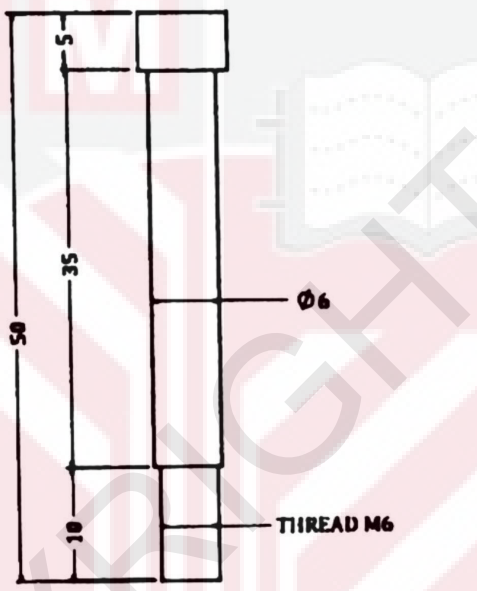


Figure 3.27 Schematic Diagram of Locking pin

Figure 3.28 The Locking pin of Dabai Nutcracker

3.7.9 Base

This is the main floor of this tool, functioning as the main holder of all the components found in this tool. Made of lightweight and hard material (aluminum7075) aimed at reducing the weight of this tool. This part is included with four table holes with the purpose to bolt down the base to a table top or a platform so that it is not moving while work is being done as shown in Figure 3.29 and Figure 3.31. All the dimensions of this part are included in Figure 3.30 below.

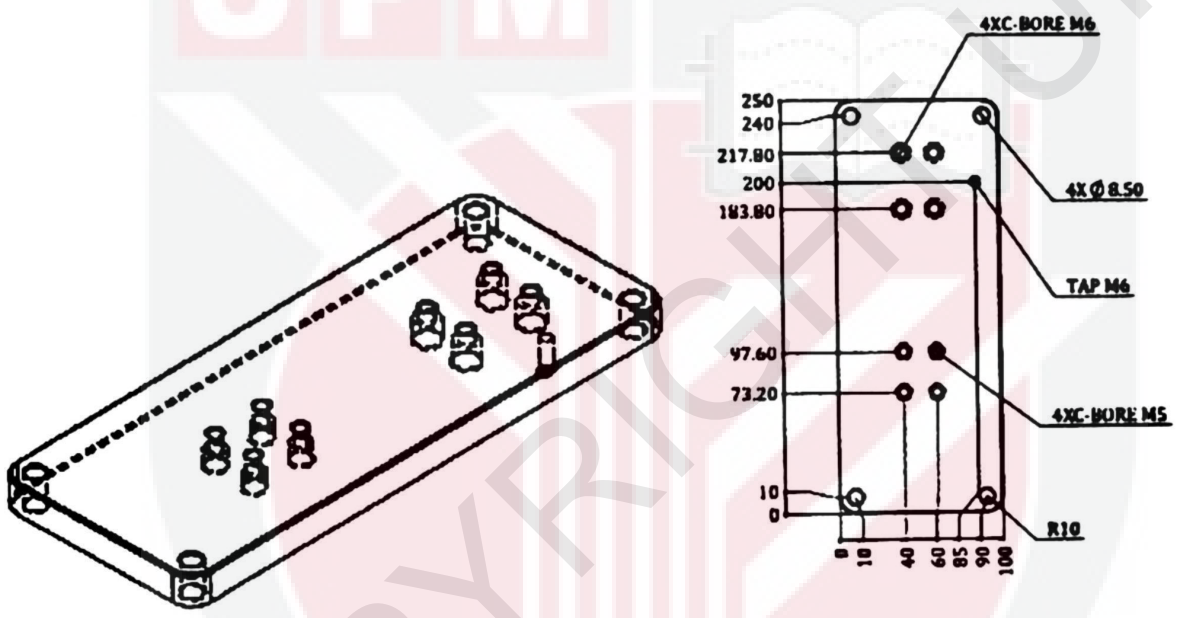


Figure 3.29 Schematic Diagram of Base

Figure 3.30 Base of Dabai Nutcracker

3.8 Machine Operation

Figure 3.31 shows the overall flow process involved in the cracking and separation of Dabai Nuts. The nuts loaded into the jig holder. Jig holder slid into guide die. The jig holder pushes towards under the top die. When under the top die, the bearing rolls when is pushed by the press handle and consequently lower the top die and compressing the nuts underneath. With enough force and traction the nuts will be cracked under pressure. Then the next slot on the jig holder is undergoes the same procedure. When all slots done cracked, the shell and the kernel is separated manually as it is already easy to separates as less damage is done to the kernel and shell and both of the material is not mixed up.

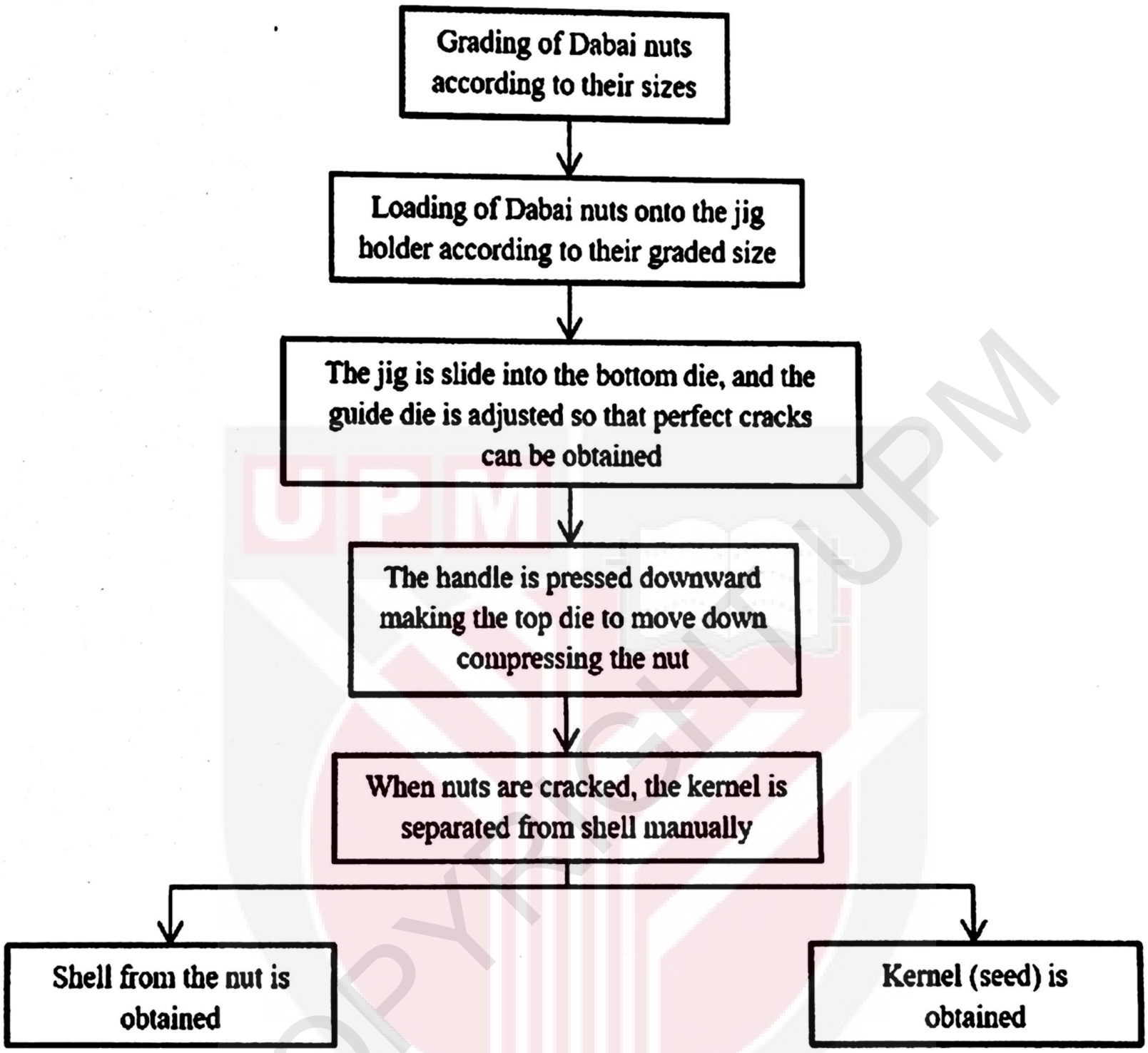


Figure 3.31 Flow Process of Cracking and Separation of Dabai Nuts

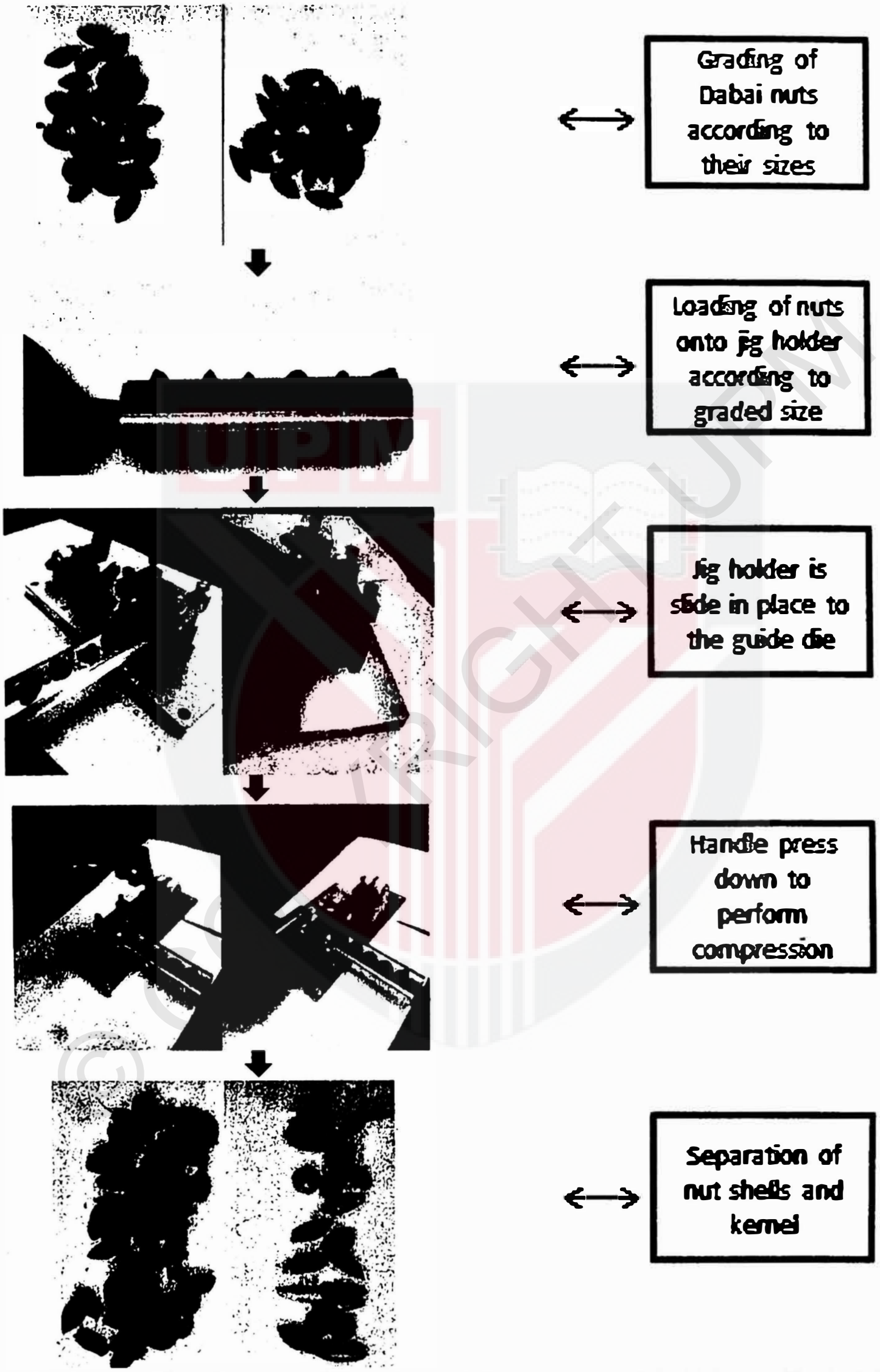


Figure 3.32 Flow Process of Cracking and Separation of Dabai Nuts (with photo)

3.9 Performance test of the tools

Performance test is done to identify the defects of the tools for further improvement based on the production capacity and/or other related parameters.

3.9.1 Determination of production capacity of cracked nuts

Before the performance test is done, the tools need to be fabricated and assembles completely. The loading orientation of the nuts is set to be longitudinal as it produces more effective cracks and easier access to the kernel without crushing the kernel. The loading orientation is decides to be longitudinal based on preliminary studies which shows the best set of orientation of the nuts to be cracked.

The samples of dabai nuts are selected randomly and 3 experimental replications were carried out with time recorded using a stopwatch. Average production for each category of size of dabai nuts is calculated. The production capacity can be determined by using the equation (8) below.

$$Production\ capacity = \frac{number\ of\ dabai\ nuts\ fully\ cracked\ (kg)}{time\ taken\ to\ fully\ cracked\ nuts\ (hr)} \quad (8)$$

3.9.2 Determination of performance efficiency of Dabai Nutcracker

The performance efficiency of the Dabai Nutcracker is evaluated based on the capability of the tools to fully cracked open nuts. The justification of the cracking process is based on the circumstances of the kernel from the shell. The efficiency of the tools also is determined. The efficiency of the Dabai Nutcracker can be calculated using the equation below. Three samples weight of 100 g of nuts is used for each sampling. Fully cracked nuts are weigh after cracking process is done. Not fully nuts also is weigh

after cracking process is done. All the results is tabulated in Table 4.14. Calculation of Tools Efficiency is based on equation (9) below.

$$Efficiency = \frac{weight\ of\ nuts\ fully\ cracked}{total\ of\ sample\ weight}\ x\ 100\ \% \quad (9)$$

3.10 Safety Factor

In any design and fabrication projects, the most important thing need to be considered is safety. Safety is vital to ensure any unwanted harms or accident occurs. Listed below are some factors that have been considered:

Instron machine compression testing need to be covered as the nut is cracked due to the continuous force from the plate, some shells have potentials to fly away. If safety is neglected, the fly away piece of the shells might hit unwanted parts of our body especially the eyes.

The holder part of the nuts or the jig of the tools needs to be adjusting the position of the nuts carefully before proceeds with the cracking process. Don't adjust while cracking the nuts as this might leads to injuries.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Machine Design

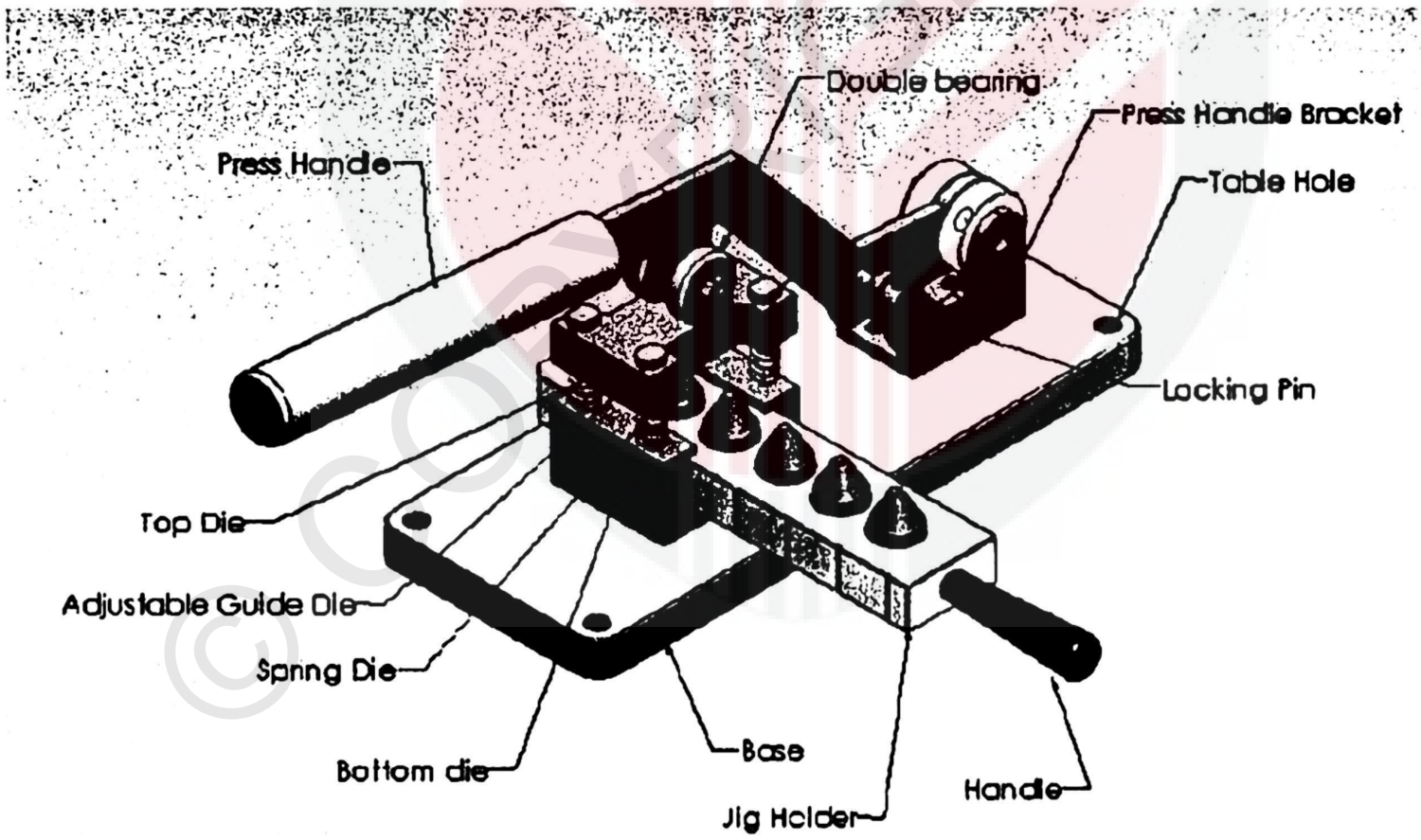


Figure 4.1 Components in Dabai Nutcracker

Figure 4.1 shows the Dabai Nutcracker that had been developed by using SOLIDWORKS software. The main components of the invention are the press handle, top die, adjustable guide die, spring die, bottom die, the base, jig holder, jig holder handle, locking pin, table hole, press handle bracket and double bearing. The detailed of design drawings are shown in Appendix A1 to A10. The dimension of the tool is 250 mm (bottom part length) / 351 mm (top part length) x 100 mm (width) x 144.09 mm (height). The operation of the tool is carried manually with the use of a single manpower.

The nutcracker is invented with a Jig holder with five mould spaces design to hold nuts vertically to ease cracking process and greater results. The mould designed to hold nuts 90 degrees. Comes in three different size based on the diameter of the dabai nuts. Design with a plastic handle to ensure user friendly. Double bearing is used to avoid the friction to the top die as it can cause damage. It also is being used to improve the accuracy of cracking when the top die is pushed down. The press handles acts as the pusher of the top die during cracking process. Locking pin system is design when the tools are not in used, the pin can be lock. This is to avoid unnecessary accident happen without realizing it and also ease the user when carrying the tool around. The base of the tool acts as the main holder for the entire component. The material of this part is made from lightweight hard material (aluminium7075). The top die is the main component where it is design with a crater shape mould and acts as the cracker. The mould is made to ensure the cracking process is carried out when the nuts is in 90 degrees position.

Spring die is being used in this design just to make sure the top die get back into its origin position after cracking process done. Adjustable guide die is the holder for top, bottom and spring die. This is important during tool operation where acts as the rail for top die to move gracefully and accurate. It is invented so that can be adjusted in terms of the height so that top die can follow the height of the nuts. Bottom die acts as the path for the jig holder to move towards under the top die during the operation of the tool. Bottom die acts as the path for the jig holder to move towards under the top die during the operation of the tool.

The nuts are load to the jig holder accordingly to its size, and then the mention jig holder is slotted in through the bottom die, where the bottom die acts as the path for the jig holder. After the jig is slotted in, the first nuts is cracked when it reach under the top die. To ensure the cracking process to run smoothly and give greater result, the adjustable guide die is adjusted according to the nut height. After adjusting, then the press handle is pushes down, where it slowly touches the top die. When the press handle touch the top die, the force will moves the top die in downward direction until it reach the nut on the jig. The nut is then cracked open with good opening so that the kernel inside can be retrieve easily because the shell of the nut is not scattered or crush and mix with the kernel.

4.2 Parameters in Designing Dabai Nutcracker

4.2.1 Physical Properties of Dabai Nut

Some of the physical properties of Dabai Nut are important in designing the nutcracker. The dimensions of the nuts such as its length, width, and height are to be obtained to get the mean or average size of the Dabai Nut to further design the tool. The jig holder is affected by the reading of the Dabai nut average size. 10 samples of each bigger and smaller dabai nut were randomly selected and the size of the nut is measured and tabulated as shown in Appendix B. Table 4.1 and Table 4.2 below shows the mean value obtained from the samples measured.

Table 4.1 Mean Dimensions of Dabai Nut (Bigger Size)

Nut Length ± Std Dev. (mm)	Nut Width ± Std Dev. (mm)	Nut Height ± Std Dev. (mm)	Geometric Mean Diameter (mm)	Nut Sphericity (%)	Aspect Ratio (%)
34.25 ± 0.98	15.56 ± 1.74	12.19 ± 0.65	18.66	54.48	45.43

Table 4.2 Mean Dimensions of Dabai Nut (Smaller Size)

Nut Length ± Std Dev. (mm)	Nut Width ± Std Dev. (mm)	Nut Height ± Std Dev. (mm)	Geometric Mean Diameter (mm)	Nut Sphericity (%)	Aspect Ratio (%)
25.84 ± 1.01	17.18 ± 0.59	15.84 ± 0.72	19.16	74.15	66.48

From Table 4.1 and Table 4.2, observation of the Dabai Nut size is observed and measured. For the bigger size nut, the average length is 34.25 mm, the average width is 15.56 mm and the average height is 12.19 mm while the smaller size nut, its mean length is 25.84 mm, mean width is 17.18, and its mean height is 15.84 mm. Therefore, the jig holder is designed to be having the opening of 15.00 mm in radius and 20.00 mm in radius. This is to ensure the nuts can be loaded perfectly into the jig holder. The length of bigger nut is 24.5 % more than the smaller nut. The width of bigger nut is 9.4 % less than smaller nut. The Height (Thickness) of bigger nut is 23.04 % less than smaller nut.

Table 4.3 Mean Weight of Dabai Nut (Bigger size) before and after pretreatment

	Initial weight (g)	Weight after drying at 50°C for 10 hr (g)
Kernel	0.58	0.53
Shell	3.52	2.99
Nut	4.11	3.52

Table 4.4 Mean Weight of Dabai Nut (Smaller size) before and after pretreatment

	Initial weight (g)	Weight after drying at 50°C for 10 hr (g)
Kernel	0.43	0.39
Shell	2.56	2.18
Nut	2.99	2.58

From Table 4.3 and Table 4.4 the mean weight obtained before and after drying process. As for bigger size nut, for the kernel it has decreased from 0.58 g to 0.53 g and the shell also decreased from 3.52 g to 2.99 g. The sum of weight of the kernel and shell gives the weight of the nuts. For bigger size nut, it has decreased 14.4 % from its original weight. As for the smaller size nut, the kernel weight decreased from 0.43 g to

0.39 g and the shell decreased from 2.56 g to 2.18 g. For the Nuts, there has been decreased 13.7 % from its initial weight. 5 samples of each bigger and smaller nut are randomly picked. All of these results in Appendix C show that, during drying process, the main factor of the nuts losing its weight is because of the loss of moisture content.

Because of the pretreatment suggested, by drying the nut under the circumstances stated, certain amount of the moisture will be removed from the nut and it will become dry. Cracking and breaking process will be much easier because the nut can give higher yield. From the result obtained in Table 4.3 and Table 4.4, moisture content remove from the nut can be calculated using equation (3)

Table 4.5 Moisture Content of Nut

	Bigger Size Nut	**Smaller Size Nut**
Moisture Content of Nut	14.23 %	13.74 %

The initial weight of the nut before drying and the final weight of the nut after drying process are measured to calculate the percentage of moisture removed from the drying process using oven at 50°C for 10 hours which implicates or similar to 3 days of sun drying. Calculation of moisture remove is based on equation (2).

Table 4.6 Summary of Moisture Removed from Nut shell (Big size)

Moisture remove (%)	15.36

Table 4.6 indicates the percentage of moisture removed from the nut shell (big size nut) after being dried under similar sun drying effect which is by using oven drying

for 10 h at 50 °C according to (Gallegos *et al.*, 2013). The result shows that the moisture removed is 15.36 %.

Table 4.7 Summary of Moisture Removed from Nut shell (Small size)

Moisture remove (%)	16.33

Table 4.7 concludes the percentage of moisture removed from the nut shell (small size nut) after being dried in similar situation as result in Table 4.6. The result obtained from Table 4.7 shows that the moisture removed is 16.33 %.

Table 4.8 Bulk Density & True Density of Dabai Nut

	True Density (g/ml)	Bulk Density (g/ml)
Bigger Nut	1.11	1.08
Smaller nut	1.25	1.21

The result shows that the true density and bulk density for bigger size nut only has small significant difference, this means that the nut has less pores and voids within the nut. Same goes to the smaller size nut. This is also important in cracking the nuts and designing the tool as dried nuts has higher tendency to easily break when force is applied.

4.2.2 Mechanical Properties of Dabai Nut

Table 4.9 Force Deformation at Fracture for bigger size nut

Description	Bigger size nut	
Sample	Compressive load at Break (N)	
	Longitudinal Orientation	Transverse Orientation
1	13.70	209.96
2	44.88	121.17
3	201.25	301.79
4	239.70	46.54
5	106.34	68.52

From Table 4.9, the compressive load to break the bigger size nut for longitudinal orientation is 13.70 N, 44.88 N, 201.25 N, and 239.70 N and 106.34 N while for transverse orientation, the compressive load to break the bigger size nut is 209.96 N, 121.17 N, 301.79 N, 46.54 N and 68.52 N. The results obtained shows insignificant pattern of the compressive load to break the nuts of similar size group. The conclusion to this is due to the level of maturity of the nuts and its moisture content level of the nut itself.

Table 4.10 Average Compression load at Break for bigger size nut

Description (Big Size)	Compressive load at Break (N)	
	Longitudinal	Transverse
Maximum	239.70	301.79
Minimum	13.70	46.54
Average	121.17	149.60
Standard deviation	97.53	105.84

From Table 4.10 obtained is the average compressive load to break the bigger size nut for both cracking in longitudinal and transverse orientation formation. For longitudinal orientation, the maximum force needed to break the nut is 239.70 N, the minimum force needed is 13.70 N making the average force needed to break the nuts from longitudinal orientation is 121.17 N with its standard deviation of 97.53 N. On the other hand, for transverse orientation, the maximum force needed to break the nut is 301.79 N and the minimum force is 46.54 N. The average force needed to break the transverse orientation nut is 149.60 N with its standard deviation of 105.84 N. Therefore, with the Dabai Nutcracker, all this force needed to break the nut can be easily achievable because of the design of the jig and the cracking unit of the tool.

Table 4.11 **Force Deformation at Fracture for smaller size nut**

Description	Smaller size nut	
Sample	Compressive load at Break (N)	
	Longitudinal Orientation	Transverse Orientation
1	85.68	168.58
2	113.03	71.87
3	394.22	161.60
4	275.18	39.76
5	78.35	64.81

From Table 4.11, the compressive load to break the smaller size nut for longitudinal orientation is 85.68 N, 113.03 N, 394.22 N, 275.18 N and 78.35 N while for transverse orientation, the compressive load to break the smaller size nut is 168.58 N, 71.87 N, 161.60 N, 39.76 N and 64.81 N. The results obtained shows insignificant pattern of the compressive load to break the nuts of similar size group. The conclusion to this is due to the level of maturity of the nuts and its moisture content level of the nut itself.

Table 4.12 **Average Compression load at Break for smaller size nut**

Description (Small size)	Compressive load at Break (N)	
	Longitudinal	Transverse
Maximum	394.22	168.58
Minimum	78.35	39.76
Average	189.29	101.32
Standard deviation	139.85	59.47

From Table 4.12 obtained is the average compressive load to break the smaller size nut for both cracking in longitudinal and transverse orientation. For longitudinal orientation, the maximum force needed to break the nut is 394.22 N, the minimum force needed is 78.35 N making the average force needed to break the nuts from longitudinal orientation is 189.29 N with its standard deviation of 139.85 N. On the other hand, for transverse orientation, the maximum force needed to break the nut is 168.58 N and the minimum force is 39.76 N. The average force needed to break the transverse orientation nut is 101.32 N with its standard deviation of 59.47 N. Therefore, with the Dabai Nutcracker, all this force needed to break the nut can be easily achievable because of the design of the jig and the cracking unit of the tool. Therefore we define in this project that peak force needed to break the bigger size nut and smaller size nut is not more than 250.00 N and 400.00 N respectively. These values are considered into designing the tool. Smaller size nut requires more force to break, in my opinion is because it has less void or spaces inside the shell making it more compact when compare to bigger size nut. In conclusion smaller size nut needed more force to break the nut compared to bigger size nut.

4.3 Performance test of the tools

4.3.1 Determination of production capacity of cracked nuts

Table 4.13 Capacity of Dabai Nutcracker

	Number of dabai nuts fully cracked (g)	Time required (s)	Rate (g/s)	Rate (kg/hr)
Conventional method	100	385	0.26	0.94
Current method	100	220	0.45	1.64

From the data obtained and calculation using equation (8) the capacity of the tool is 1.64 kg/hr. There is 1.75 times increase in production capacity by using Dabai Nutcracker. This shows that this tool helps in increasing the productivity.

4.3.2 Determination of performance efficiency of Dabai Nutcracker

Table 4.14 Efficiency of Dabai Nutcracker

Sample	Sample weight (g)	Weight (g)		Efficiency (%)
		Fully cracked open nuts	Not fully cracked	
1	100	96.4	3.6	96.4
2	100	100.0	0.0	100.00
3	100	95.4	4.6	95.4
Average				97.27

Three sets of 100 g samples are being used in the test of determining the efficiency of the Dabai Nutcracker. From the result obtained above, the efficiency for the Dabai Nutcracker is 97.27 % which is consider being high and successfully meets the requirements of the project design.

4.4 Advantages and Disadvantages

There are some advantages and disadvantages of using the Dabai Nutcracker compared to the traditional method of cracking the nuts using mortar and pestle. The common advantage is current method gives higher production rate compared to traditional method. The use of this tool also saves more time compared to traditional method. Other than that, by using this tool, user or operator exposure to injuries is less. However the cost of fabrication and maintenance of this tool is more if compared to using traditional method as the tools use can be obtain generally in hardware store. The summary of the comparison is tabulated in Table 4.15 below.

Table 4.15 Summary of the comparison between using Dabai Nutcracker and traditional method

Current Method (Dabai Nutcracker)	Traditional Method (Mortar and Pestle)
Higher production rate	Lower production rate
Save time	Consume more time
Less risk to injury	High risk to injury
More cost in fabrication and maintenance	Less cost

4.5 Tools Modification

Several modifications can be made to improve the competency and capability of the tool once the tool performance is observed. The problems determined during the investigation period where several test run has been carried out and followed by each

problems, its suggestions to improve or solve the problems in order to improve the performance of the tool.

Table 4.16 Problems Occurred and Solutions for Improvement

Problems	**Solutions**
Dabai Nuts have various sizes where bigger sizes nut does not fit into the jig holder at first.	The jig holder holes is widen to make sure that bigger size nuts can fit in so that it can be crack open.
Dabai Nuts skin condition has high hardness and very difficult to crack manually or using hands.	Drying process can be carried out first before using the Dabai Nutcracker so that nuts have lower moisture content and easy to break.
Press handle is made from steel, can be slippery when conducting the process.	Includes a rubber cover for the handle or simply wear a gloves when operating the tools to avoid slippery hands.

4.6 Precaution Steps

Prudent advances ought to be taken by the client to evade any undesired mishaps and dangers while working the device. The following are a portion of the means that can guarantee the security and strength of the client.

- Make sure to always clamp the base of the tool to a bigger base so that the tool is not moving during the cracking process
- Make sure to always wear a pair of gloves so that crack shells cannot penetrate into skin.
- Always clean after the tools to avoid wear and possibility to cause failure which can harm user.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The aim of this project has been accomplished with the fabrication of the Dabai Nutcracker. This tool will helps in the cracking Dabai nuts by removing the shell more delicately and retrieving the kernel in a whole without crushing it into mixture of shell and kernel where it will make the separation process more difficult.

The findings from physical properties determination shows that, for bigger size nut, the dimensions obtained is 34.25 ± 0.98 mm (Nut Length), 15.56 ± 1.74 mm (Nut Width), 12.19 ± 0.65 mm (Nut Height), 18.66 mm (Geometric Mean Diameter), 54.48 % (Nut Sphericity), and 45.43 % (Aspect Ratio). While for smaller size nut is 25.84 ± 1.01 mm (Nut Length), 17.18 ± 0.59 mm (Nut Width), 15.84 ± 0.72 mm (Nut Height), 19.16 mm (Geometric Mean Diameter), 74.15 % (Nut Sphericity), and 66.48 % (Aspect Ratio). The mean weight obtained before and after drying process of the bigger size nut is decreased 14.4 % while the mean weight for smaller size nut decreased 13.7 %.

The moisture content between the two sizes of nut also has different value where the bigger size nut is 14.23 % MC and smaller size nut is 13.74 % MC. This shows that the nuts moisture content is dependent on the size of the nut. The pretreatment of drying also removed moisture from the nut. A bigger size nut has the average of 15.02 % moisture removed while 14.58 % moisture is removed from the smaller size nut. In addition, the true density and bulk density for both sizes of nut has small significant difference. This shows that the nut has less pores and voids within the nut. The true density and bulk density for bigger size nut is 1.11 g/ml and 1.08 g/ml, while 1.25 g/ml and 1.21 g/ml for smaller size nut respectively.

For mechanical properties determination, results obtained shows that for bigger size nut, the maximum compressive force needed to crack the nut is 239.70 N (Longitudinal Orientation) and 301.79 N (Transverse Orientation) while for smaller size nut, 394.22 N (Longitudinal Orientation) and 168.58 N (Transverse Orientation). This tool can be operated by only one worker at a time and it is user friendly where no special skill is needed only manpower to handle the tool. The capacity of the tool is 1.64 kg/hr comparing to 0.94 kg/hr for using conventional method. This proves that there is 1.75 times increase in the production capacity. The efficiency of the tool is 97.27 %. Therefore it is highly recommended to replace the traditional cracking method which is manually by using mortar and pestle and has very high risk in injuries. In addition, this tool is an innovation based on the preliminary studies on the Dabai nuts and design especially for Dabai nuts. Therefore more research and development of this tool need to be done for an improved tool for the future.

5.2 Recommendation

Some modifications are essential to optimize the performance of the tool. As follows are some recommendations of modification probably that can be done to the tool.

- Includes a drying system to the tools. Although the tool is not big in size, however if an oven is installed and after drying process the nuts is transferred through a conveyor to the jig mould where it is automatically fill in the mould of the jig. Then operator of the cracker can easily take the jig and slot into the Dabai Nutcracker.

- The jig holder with only 6 mould can be modified into an increased amount of mould. This also requires the cracker to be upscale so that it fits the jig holder mould. This will definitely improve the performance capacity of the nutcracker.

- All of this is recommended to be installed with a system so that it will operate automatically. More precision, accuracy and less human error will occur. The performance capacity can be increased, efficiency of the tools can be increased, less cost is needed to pay salary of the operator, only for maintenance and lastly avoid the risk of injuries to human.

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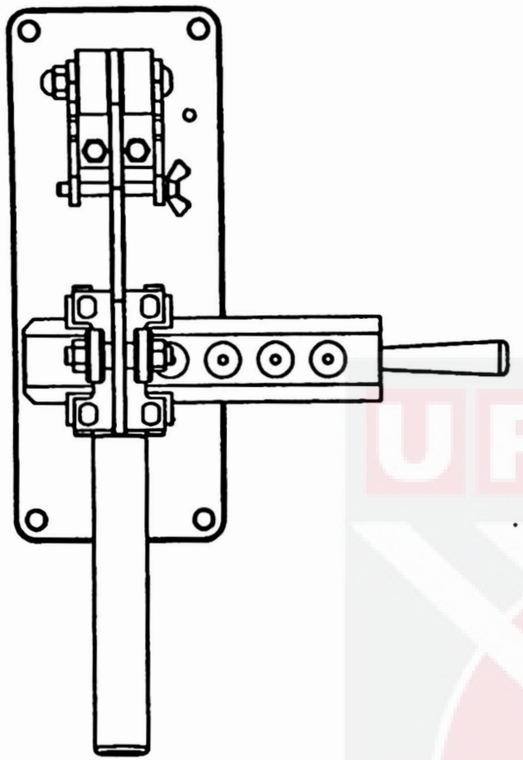
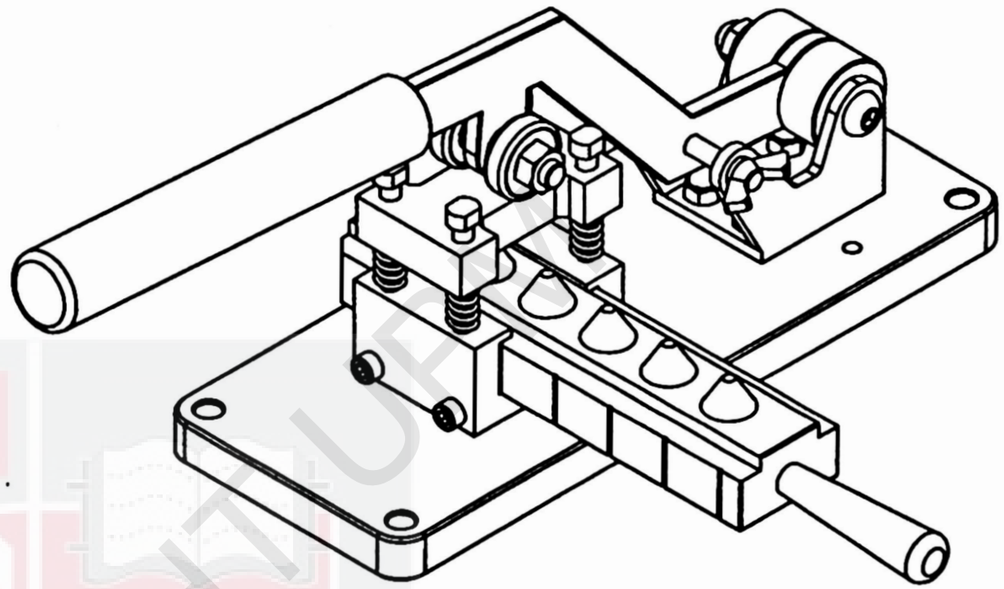
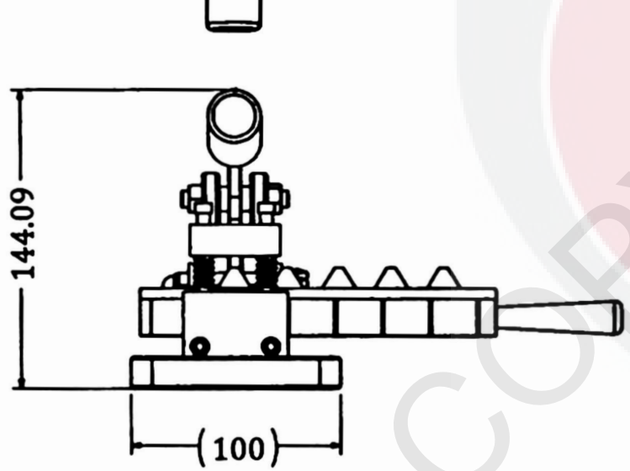
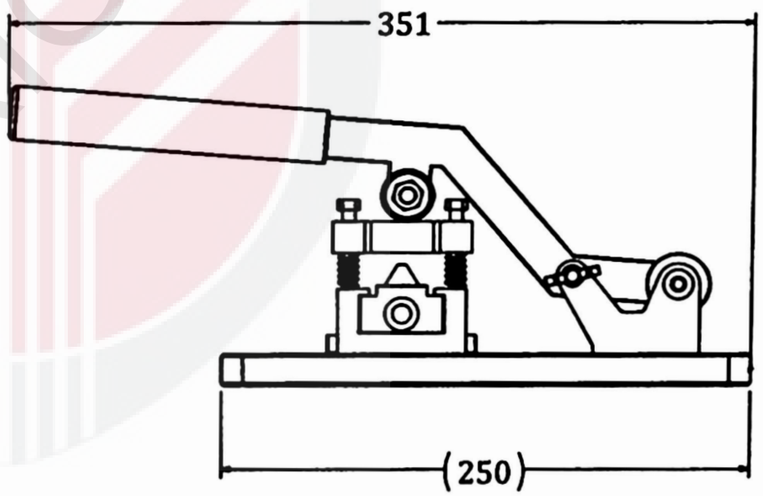
APPENDIX A









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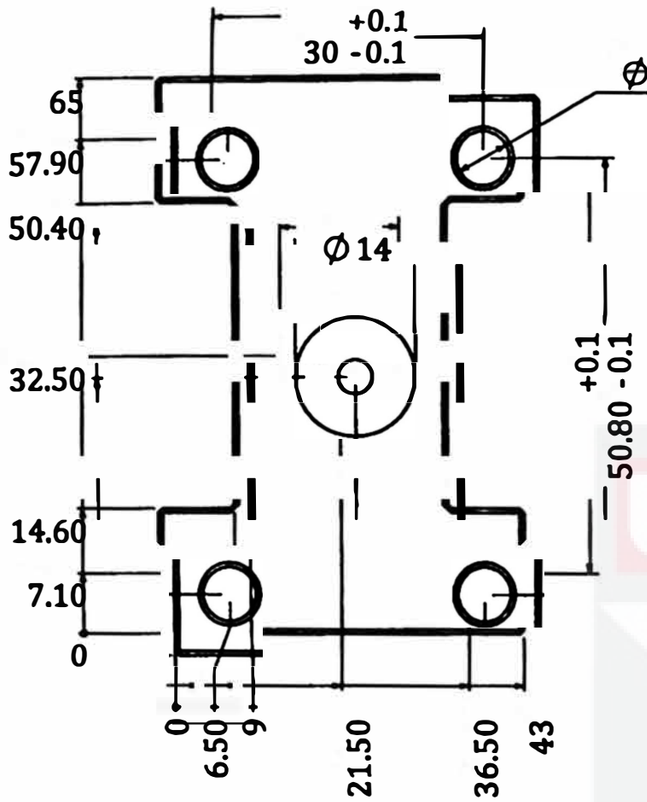

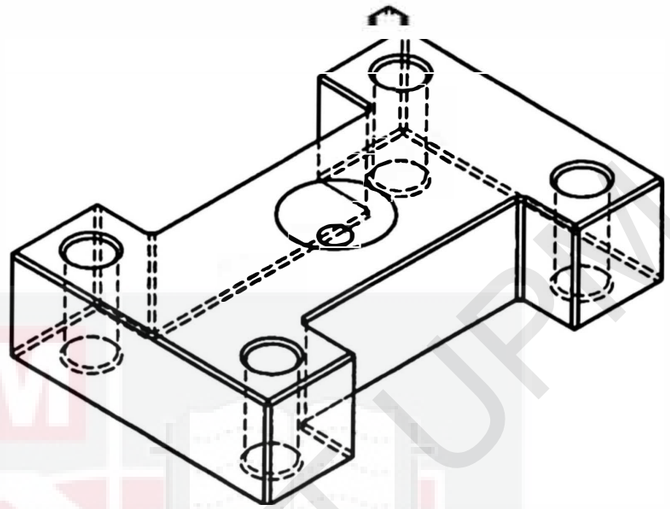

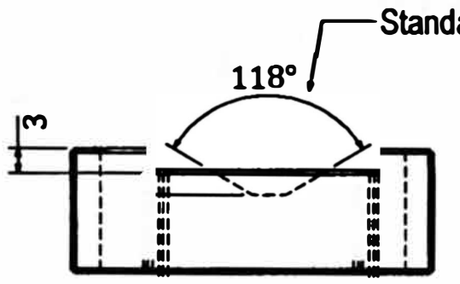

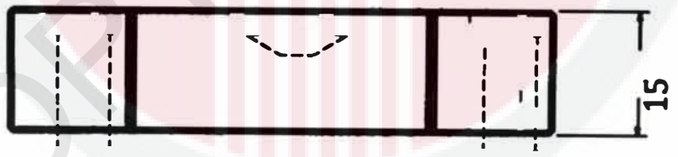

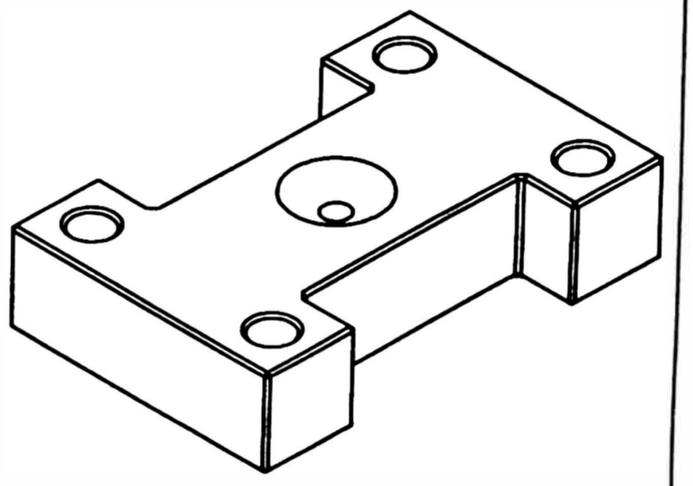

IPS ENGINEERING

ipro Designer IPS

H/P:0173991996
Email : iproskill@yahoo.com.my

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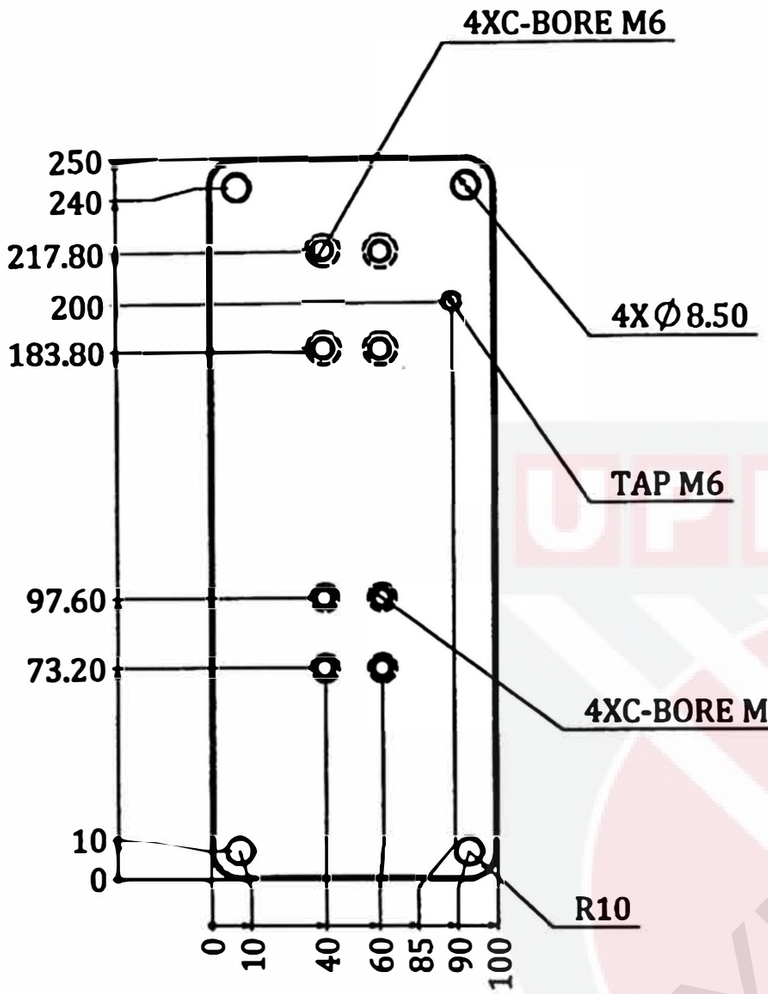

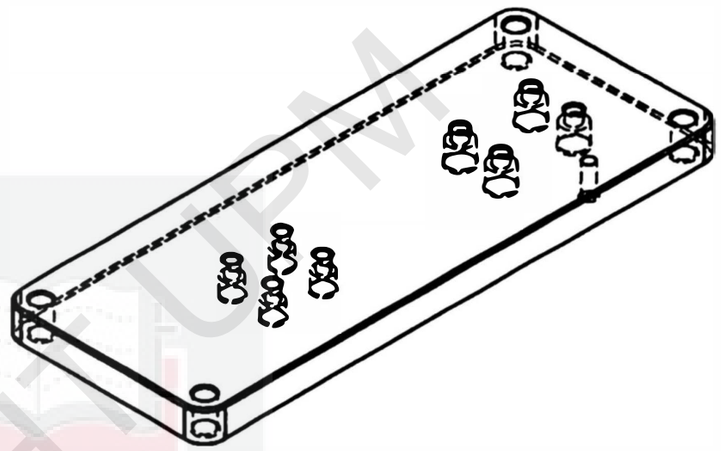

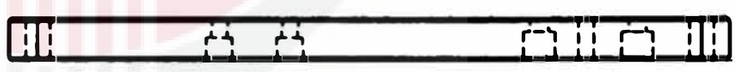

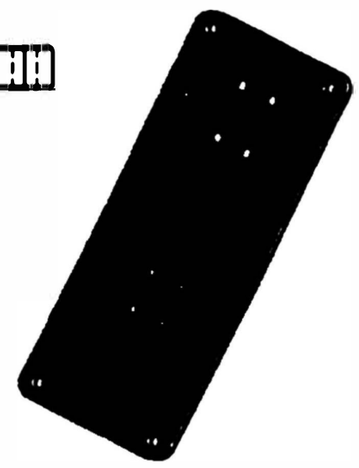

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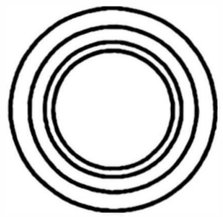

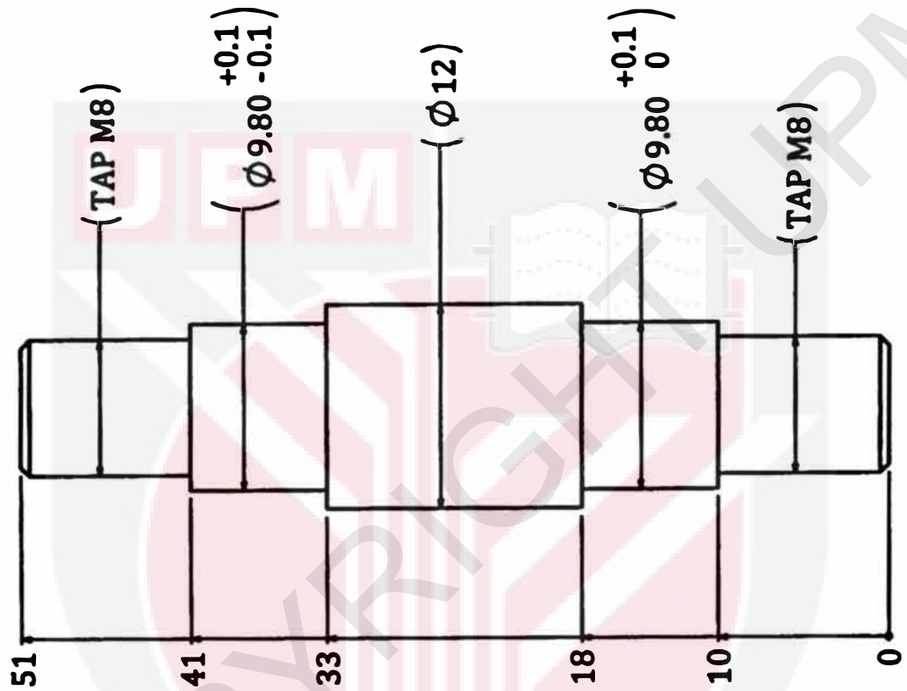

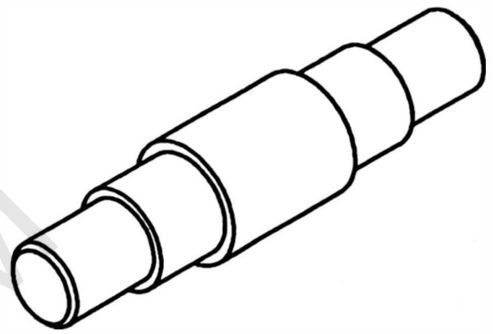

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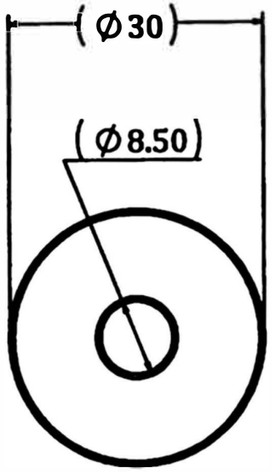

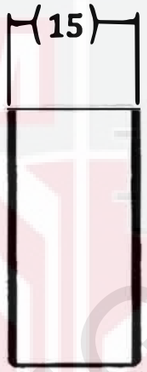

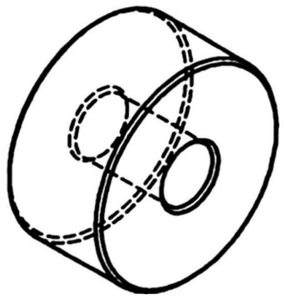

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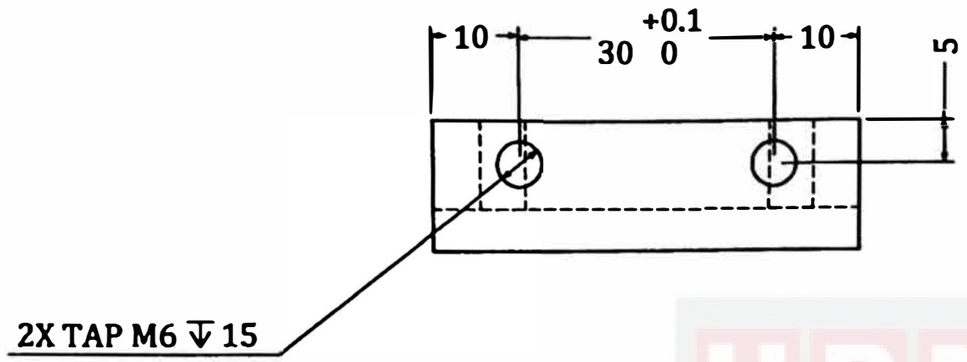

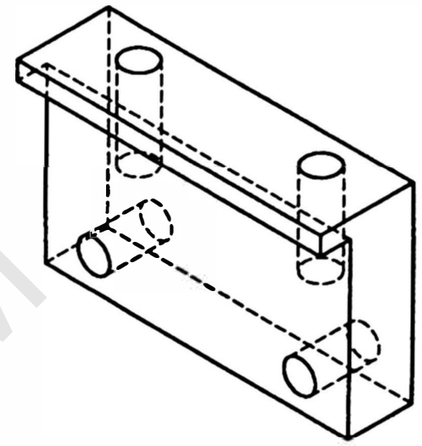

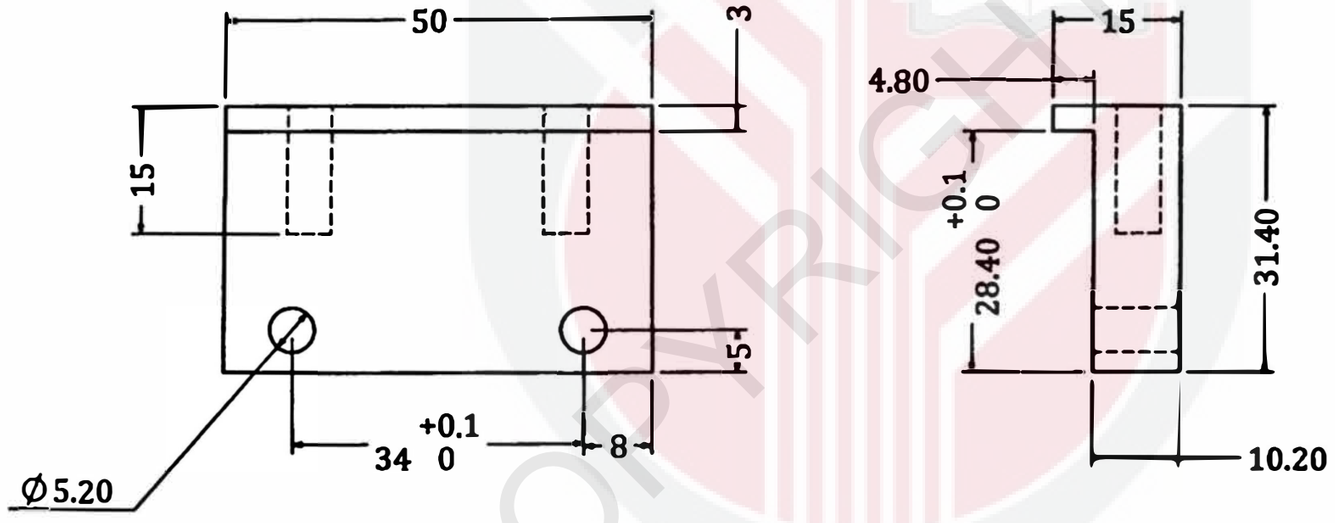

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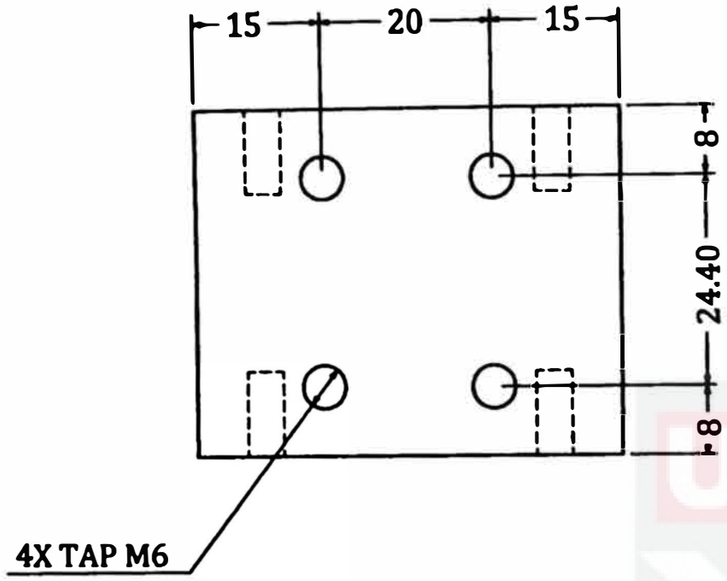

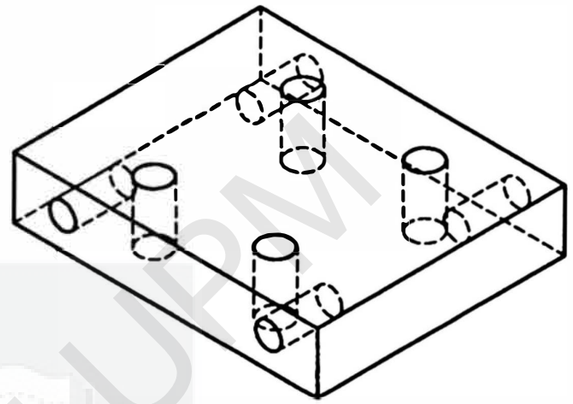

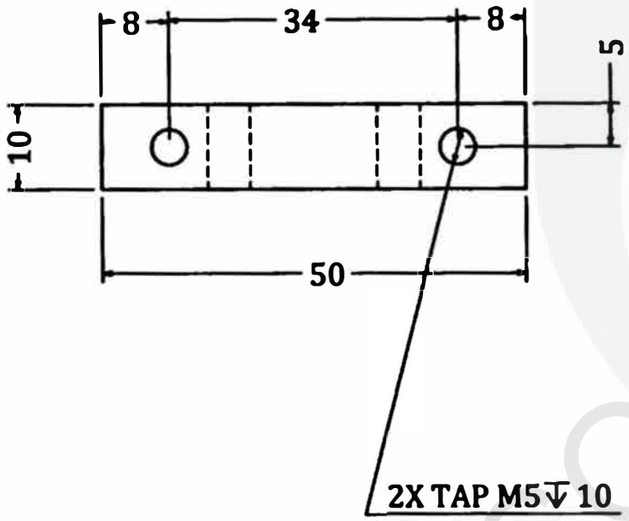

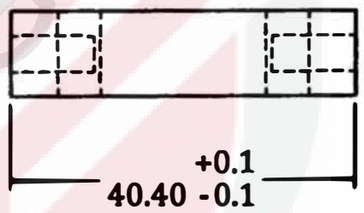

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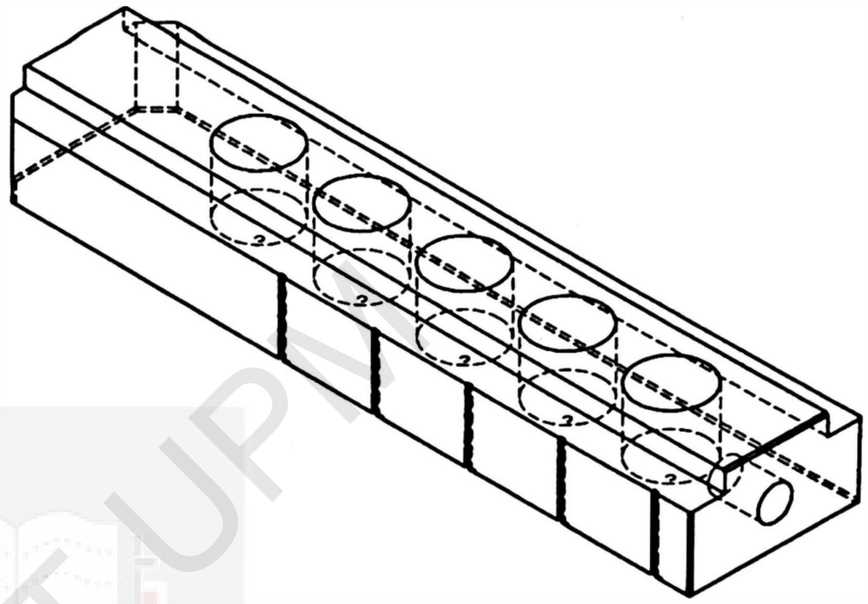

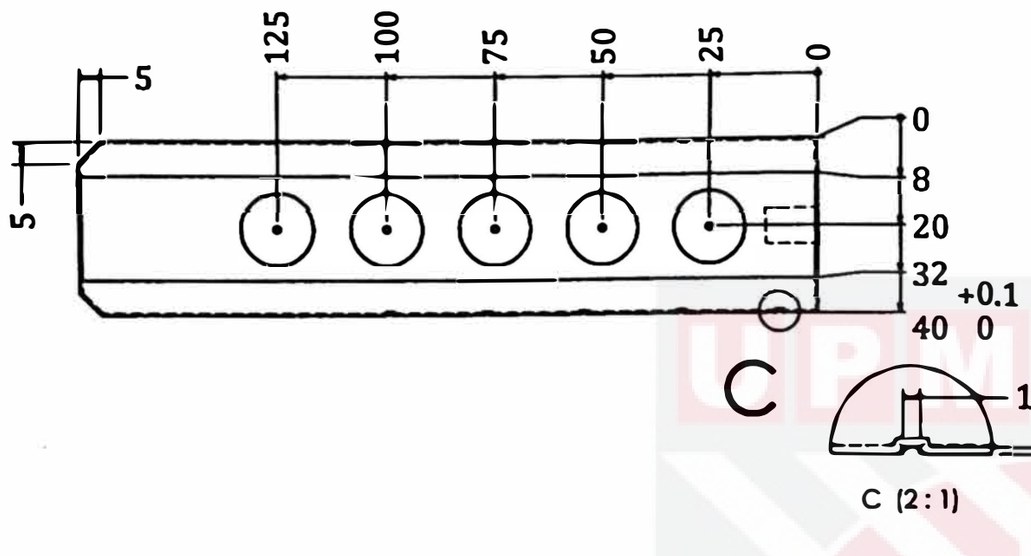

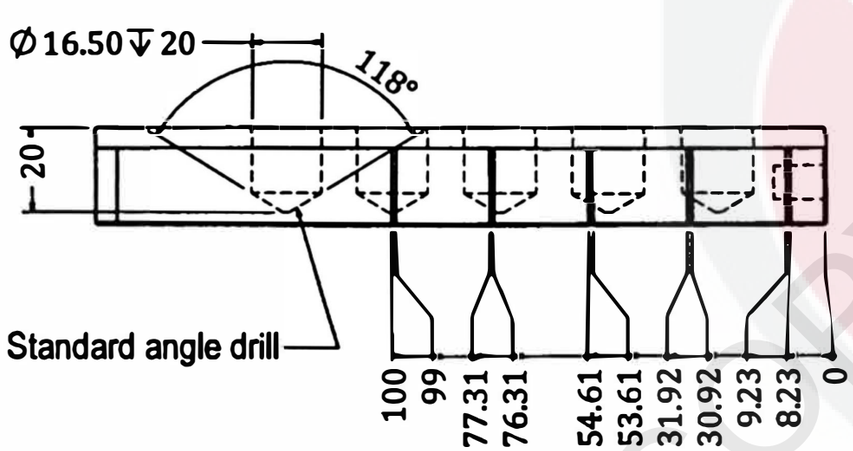

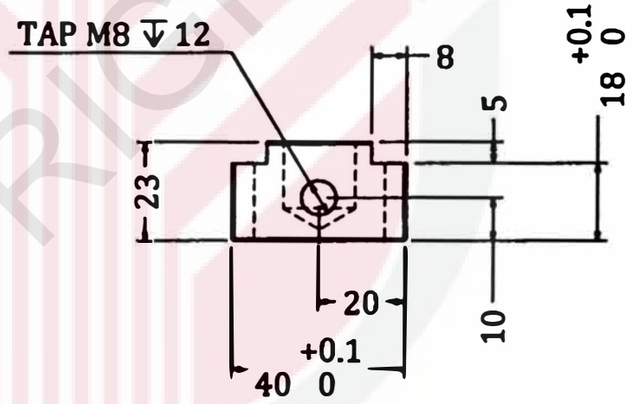

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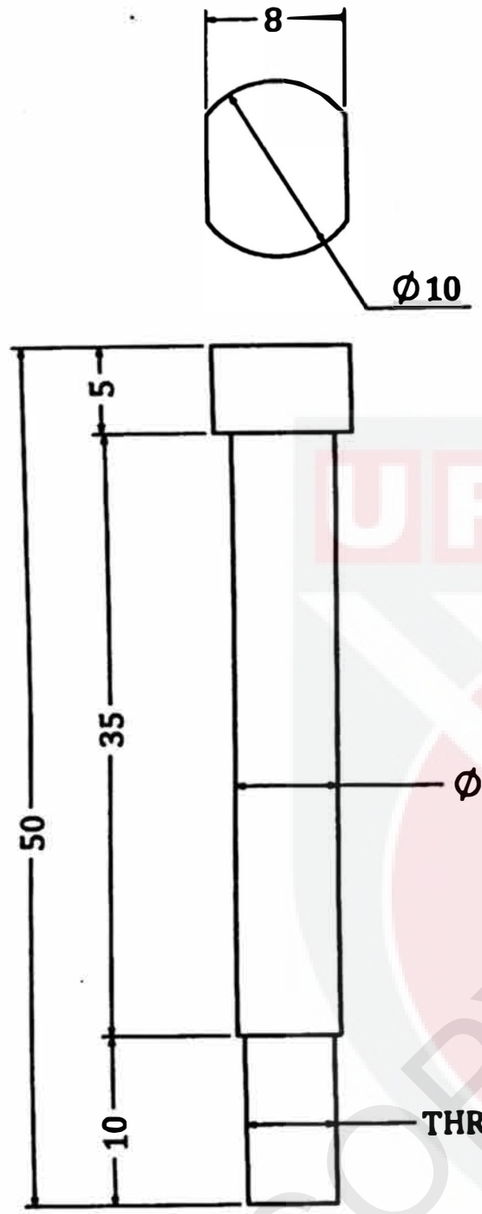

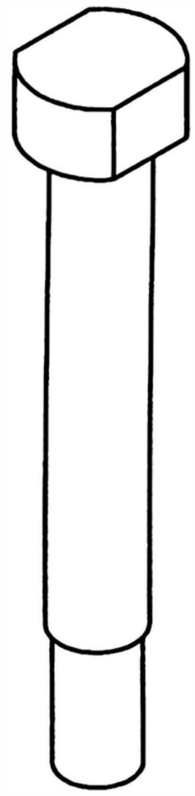

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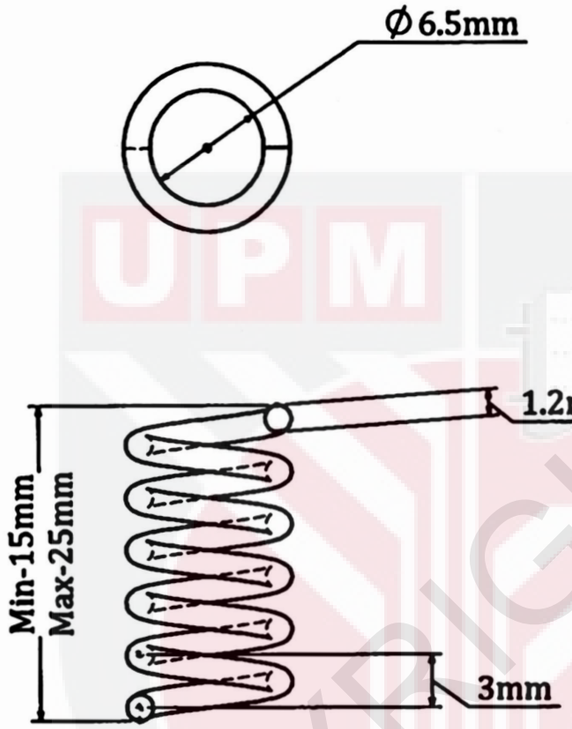
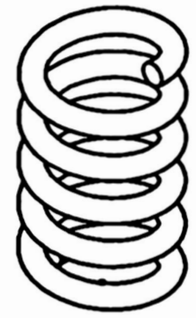
	MATERIAL	sus304
H/P:0173991996 Email : iproskill@yahoo.com.my	QTY	4-Pcs





IPS ENGINEERING	ipro Designer IPS	(General tolerance ±0.2),(Finishing,no burr),(All edge,angle- chamfer 0.5mm)	
		PART NAME	spring
		MATERIAL	SPING STILL - SUS304
H/P:0173991996 Email : iproskill@yahoo.com.my		QTY	4-Pcs

APPENDIX B

MEAN DIMENSIONS OF DABAI NUT (BIGGER & SMALLER SIZE)

Table: Average dimensions of Dabai Nut (Bigger size)

Sample	Length	Width	Height
1	32.67	16.79	12.25
2	35.34	14.16	12.2
3	34.6	17.26	12.92
4	34.57	14.18	12.95
5	34.25	16.4	11.47
6	34.33	13.25	11.5
7	33.63	17.03	12.28
8	32.71	13.45	12.51
9	35.06	18.02	12.77
10	35.36	15.09	11.06
Average	34.25	15.56	12.19
Std Deviation	0.97	1.73	0.65

Table: Average dimensions of Dabai Nut (Smaller size)

Sample	Length	Width	Height
1	25.96	16.79	15.48
2	24.52	16.46	15.43
3	25.32	17.26	15.41
4	26.53	17.55	15.03
5	25.46	16.4	16.07
6	27.55	17.52	16.94
7	25.34	17.03	16.32
8	24.81	16.78	16.93
9	25.59	18.02	14.92
10	27.35	18.05	15.91
Average	25.84	17.18	15.84
Std Deviation	1.01	0.59	0.72

APPENDIX C

AVERAGE WEIGHT OF DABAI NUT (BIGGER & SMALLER SIZE)

BEFORE & AFTER PRETREATMENT

Table: Average weight of kernel (Bigger size)

Sample	Initial weight	Final weight
1	0.6585	0.6071
2	0.5939	0.5373
3	0.4935	0.427
4	0.6469	0.5871
5	0.5478	0.5055
Average	0.58812	0.5328

Table: Average weight of shell (Bigger size)

Sample	Initial weight	Final weight	Moisture removed	% of Moisture Removed
1	3.7925	3.2357	0.5568	14.68
2	3.7586	3.1867	0.5722	15.22
3	2.8341	2.413	0.4211	14.86
4	3.5942	3.0419	0.5523	15.36
5	3.6047	3.0634	0.5413	15.01
Average	3.51688	2.98814	0.5287	15.026

Table: Average weight of kernel (Smaller size)

Sample	Initial weight	Final weight
1	0.5205	0.473
2	0.507	0.4598
3	0.2292	0.209
4	0.4325	0.4001
5	0.4515	0.4196
Average	0.42814	0.3923

Table: Average weight of shell (Smaller size)

Sample	Initial weight	Final weight	Moisture removed	% of Moisture Removed
1	2.7608	2.3098	0.451	16.34
2	2.6827	2.2587	0.424	15.8
3	2.4305	2.0947	0.3358	13.82
4	2.4033	2.0286	0.3747	15.6
5	2.5141	2.2282	0.2859	11.37
Average	2.55828	2.184	0.3742	14.58