DESIGN OPTIMIZATION OF A VERTICAL TYPE PAPAYA GRATER USING QFD METHODS

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Abstract. *Market demand for papaya processed products such as papaya dodol, jam, and sweets is increasing, so tools are needed that can speed up the processing process, especially grating papaya. This study aims to optimize the design of papaya grater machine by using QFD method approach. This method is used to produce a systematic and efficient design through structured stages, starting from needs analysis, function formulation, solution development, to final design. In the process, various alternative concepts were evaluated based on the criteria of performance, ergonomics, ease of maintenance, and production costs. The optimization results show that the final design of the machine has a capacity of 10 kg/hour with an increased work efficiency of up to 45% compared to the manual method. The machine was also designed with ease of operation and user safety in mind. With the QFD approach, the design process becomes more focused and produces products that are more optimal for the needs of the home industry and MSME scale.*

Keywords: *Design Optimization; Papaya Grater Machine; QFD Method Systematic Design; Work Efficiency.*

1. INTRODUCTION

Papaya, often referred to as Betik, is a variety of fruit plant that has a number of benefits. The plant with the scientific name Carica papaya is native to the tropical regions of Central America and southern Mexico. Today, papaya has spread to many countries with tropical climates, including Indonesia. In addition, papaya has also successfully adapted to areas such as the Caribbean, Florida, Texas, California, Hawaii, and other tropical and subtropical regions. In Indonesian, the word papaya is derived from the Dutch term 'papaja'. In Javanese, the fruit is known as 'kates', while in Sundanese it is called 'gedang'. In Indonesia, papaya is one of the most popular fruits and is widely favored by the public (Budi, 2023).

Papaya fruit contains the highly active enzyme papain, which is useful for accelerating the digestion process of proteins, carbohydrates, and fats. In addition, papaya is also rich in various active compounds such as carotenoids, alkaloids, flavonoids, monoterpenoids, minerals, and vitamins C, A, B, and E (Simanjuntak, 2023).

In countries in Southeast Asia, raw papaya is widely processed into various types of food. In Indonesia, immature papaya and young papaya leaves are often used as fresh vegetables, cooking ingredients, and in traditional medicine (Kurnia, 2018).

Food security is closely related to the agricultural sector in general, which includes food crops, fisheries, livestock, gardens, and horticulture. One of the biggest challenges in the agricultural sector is the lack of human resources (HR) capable of applying the latest technology. Most production processes still rely on the use of manual or simple tools. In addition, the agricultural sector is dominated by Micro, Small and Medium Enterprises (MSMEs) that still rely on manual tools, with limited capacity to purchase automated machinery due to high costs. Therefore, manual tools remain the main choice at this time. Until now, there is no efficient young papaya chopping machine available. Given the various challenges that arise, especially in the home industry, a better tool design is needed to support productivity and meet market demand. The design of the

young papaya chopper is expected to be an innovation from the current chopping tool, which is primitive, inefficient and manual. With the development of this tool, the chopping process in the production line can take place more easily. The development of this tool can also speed up the production process and save time, and make it more practical in terms of economy and maintenance. Thus, the creation of this tool will provide benefits to users (Fatkhurrohman, 2020).

In developing a product, one method that can be applied is Quality Function Deployment (QFD). This method is effective for converting subjective customer needs into technical requirements, as well as setting priorities for technical statements in the product development process (Kurniawan, 2024).

Based on the above background, the author plans to optimize the design of a vertical type papaya grater by applying the QFD methods. The goal is to assess the performance of the papaya grater and its ability to carry out the grating process, while optimizing the functionality of the grater to achieve optimal results.

2. LITERATURE REVIEW

2.1 Design

The design of a device that has a goal not only to create a device that functions optimally, but also to make cost savings, that is, the device made is sought to provide the lowest annual cost. The annual cost includes the depreciation cost of making the tool (investment in making the tool divided by the life of the tool) as well as the cost for operations (use and maintenance of the tool) (Mujiburohman, 2022).

2.2 Grating Machine

With the papaya grater that utilizes an electric motor, time and cost savings can be achieved. This tool functions with an electric motor that has a maximum speed of 2800 Rpm or a power of 200 watts. On the shaft of the electric motor, there is an additional shaft connected to the cutting tool (blade). When the motor is activated and the main shaft of the electric motor rotates, the energy flowing into the shaft of the cutting tool will also move, so that it can grate the material that enters through the hooper in and out through the hooper out in the papaya grater machine (Ananda, 2023).

2.3 Working Mechanism of Grating Machine

With the papaya grater that utilizes an electric motor, time efficiency and cost savings can be achieved. This tool functions by using an electric motor that has a maximum speed of 2800 Rpm and a power of 200 watts. On the shaft of the electric motor, there is another shaft connected to the cutting tool (knife). When the motor is activated and the main shaft of the electric motor functions, the power passed to the shaft of the cutting tool will also move, so that it is able to grate the material that is inserted through the hooper in and out through the hooper out on the papaya grater machine (Ananda, 2023).

2.4 Papaya Grating Machine Parts

Part of the papaya grater machine consists of the following:

1. Electric Motor

An electric motor is a device that is responsible for converting electrical energy into mechanical motion, which in this case is rotation. These motors can be found in various electrical devices such as papaya graters, fans, pumps, washing machines, mixers, vacuum cleaners, and others.

Below are the various types of electric motors grouped by power source, structure, and mode of action listed in the electric motor category. In general, there are two types of electric motors, namely AC electric motors and DC electric motors.

2. DC motor

As the name suggests, DC motors or direct motors use direct current that does not change direction. These motors are used in certain situations that require high torque or

steady acceleration over a wide speed range. The appearance of a DC motor is shown in Figure 1 below.

Figure 1. DC Motor

Based on the illustration of the DC motor, the explanation is as follows:

a. Field Poles

DC motors have two static magnetic poles, the north pole and the south pole, and a dynamo that moves the bearings between the two poles. Magnetic field lines develop as they cross the space between the north and south poles (Putranto, 2024).

b. Dynamo

The dynamo in a DC motor is cylindrical and is mounted in the right position to drive the load. When current flows into the armature, it transforms into an electromagnet. A small DC motor, generator rotates in the magnetic field created by its poles, until there is an exchange of positions between the south and north poles. When that happens, the current entering the DC motor will change direction and reverse the magnetic poles on the dynamo (Putranto, 2024).

c. Commutator

The role of this component in a DC motor is to change the direction of the electric current in the generator, the commutator also assists the DC motor in transferring current between the armature and the power source. For further explanation, see Figures 2 and 3 below:

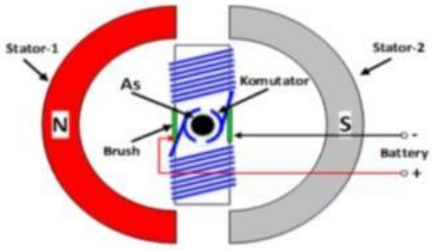


Figure 2. Stator Commutator Structure

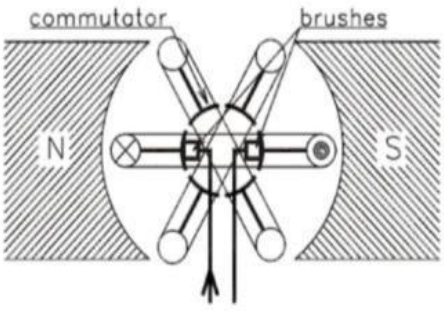


Figure 3. Stator Commutator

The benefit of using a DC motor is its ability to function as a speed regulator, without affecting the quality of energy delivered. DC motors are generally used for applications with low to medium speed and power, as they often experience challenges when

changing the direction of mechanical electricity on a larger scale. In addition, DC motors are more cost-effective compared to AC motors (Putranto, 2024).

The main advantage of DC motors compared to AC motors is the difficulty in regulating the speed of AC motors. To overcome this limitation, AC motors can be equipped with variable frequency drives, which allow for improved speed control while reducing power consumption (Putranto, 2024).

3. AC motor

AC current motor (Alternating Current) is a type of electrical machine that functions to convert electrical energy into mechanical energy by utilizing an alternating current source. Fundamentally, AC motors operate based on the principle of electromagnetic induction, where there is interaction between the stator magnetic field and the rotor magnetic field which produces torque on the rotor. In AC motors there are stator and rotor components which can be observed in Figure 4 below.

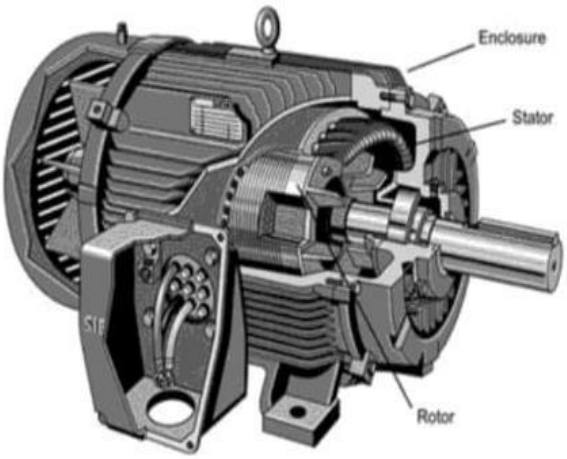


Figure 4. AC motor

Overall, an AC motor is composed of two main elements, the stator and the rotor. The stator is a fixed part consisting of coils wrapped around a coated iron core. When exposed to alternating current, the stator will create a rotating magnetic field. Meanwhile, the rotor is the moving part and is located inside the stator. This rotor can be in the form of a coil or conductor bar arranged in a certain way (Putranto, 2024).

Based on the nature of the electric current flowing, AC (Alternating Current) motors or better known as alternating current motors are divided into two types, namely:

a. AC electric motor or alternating current one phase
b. AC electric motor or three-phase alternating current (Putranto, 2024).

4. Shaft

A shaft is an element that does not move but can rotate, generally has a round cross section and is equipped with components such as gears. The shaft is able to withstand loads in the form of bending, pulling, pressure, or twisting, either separately or in combination with various types of loads.

a. Function of the Shaft

The shaft in the engine plays a role in transmitting power along with rotation. Each rotating machine component, such as rope chakra, belt pulley, cable disk, cable drum, road wheel and gear, is connected to a static or rotating support shaft. For example, the shaft that turns the faucet wheel on a cart (Nugroho, 2024).

b. Working Principle

A shaft is a circular piece of metal, used to transfer rotation or support a load either with or without transferring power. The shaft is held in place by two or more bearings.

Rotating elements supported by the shaft include power wheels (flywheels), gears, tire wheels, friction wheels, and so on (Nugroho, 2024).

Figure 5. Shaft

c. Sharp Knife

In the Big Indonesian Dictionary (KBBI), the definition of a sharp knife is the part that has sharpness on the knife. Sharp knives contained in the papaya grater can be seen in Figure 6 below.

Figure 6. Knife Blade

2.4 Analysis

Analysis refers to activities to study and assess a form of problem or situation that exists (Simanjuntak, 2023). System analysis is a step to examine and evaluate the system that is currently operating with the aim of understanding how the system functions, recognizing existing problems, and formulating needs for new systems or improvements to existing systems. This process is a very crucial initial phase in the development of information systems because it becomes a foothold in determining how the system will be designed and built (Nirsal, 2025).

2.5 Optimization

Optimization is the process of achieving the most ideal result or the most efficient value that can be achieved (Mujiburohman, 2022). Optimization activities aim to minimize effort or maximize desired profits. The required effort or desired profit serves as a decision variable, so it can be interpreted that the optimization method is a process to find conditions that provide the minimum or maximum value of a function. Optimization methods provide many benefits in decision making. The application of optimization methods is widely found in various disciplines, including engineering, economics, politics, social, and others (Anna, 2015).

In accordance with the Big Indonesian Dictionary (KBBI), optimization is rooted in the word Optimal which means best or very high. Optimization itself is an effort to make something better, or a process that aims to bring the most efficient and effective results as expected. Optimization can also be understood as a measure that makes the

maximum increase in goals so that the desired or necessary benefits are achieved (Sopanah, Ana, 2023).

2.6 Quality Function Deployment (QFD) Method

Quality Function Deployment (QFD) is a planning process that supports organizations in implementing various technical tools effectively and completely, interrelated to prioritize each issue. QFD is a method to improve the quality of products or services by understanding consumer demand and linking it with technical characteristics in order to produce a product or service at every stage of making goods or services produced (Prastato, 2023).

According to (Puji Priyono and Yuamita 2022), Quality Function Deployment is a structured methodology applied in product planning and development to determine consumer needs and wants and systematically assess the ability of a product or service to meet consumer demand. With this method, we can find out the tools expected by farmers through distributing questionnaires and realize tools that are more practical and efficient when used (Prastato, 2023).

In developing a product, one of the methods that can be applied is Quality Function Deployment (QFD) where the needs of customers and products position in the market can be depicted (Arief, 2023). This method is effective for converting subjective customer needs into technical requirements, as well as setting priorities for technical statements in the product development process (Arief, 2023).

3. RESEARCH METHODS

The research method is quantitative research (descriptive) by reviewing literature. This research was conducted by collecting information obtained from journals, books, articles, then analyzed.

This research was conducted online, by reviewing journals, articles, and books. The time of this research was from May to October 2025.

The tools and materials used for this research are: Laptop is used to access journals, articles, e-books. Saving data that has been made. Microsoft word is used to create research results, and make edits. The Mendeley application is used to create a bibliography.

4. RESULTS AND DISCUSSION

Product design is the process of creating a product based on the results of observations and interviews, which are then developed into a design concept. The main purpose of this product is to increase productivity levels. There are several stages in this process, including:

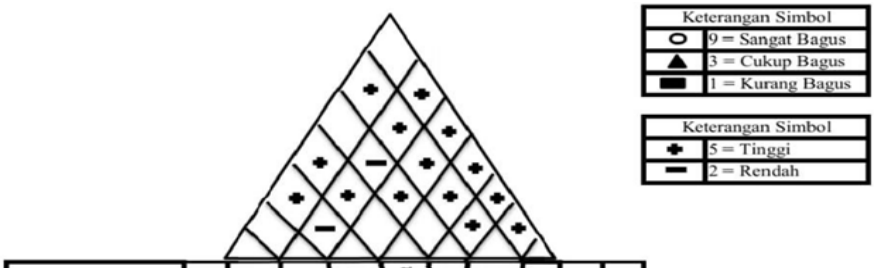
4.1 Identification of Customer Needs

At this stage, customer needs are identified through statements obtained from the results of questionnaires to MSME mothers. These statements are then translated into more specific customer needs.

4.2 Determination of Product Specifications

In determining product specifications, the QFD method is used to analyze voice of customer data on the technical attributes of the product concept. This process includes:
1. Voice of Customer (VoC) Is the voice or expectations of consumers collected through questionnaires. This data contains customer wants and needs.
2. Identification of User Needs and Technical Responses A matrix is created that describes the relationship between user needs and technical responses, based on direct observation, experience of toolmakers, and related parties.
3. Correlation of Technical Responses This is the top part of QFD that shows the relationship between one technical attribute and another.
4. The Technical Matrix is used to determine the priority of each technical response,

by giving a symbol at the intersection point between needs and technical responses.



	Bobot	Kekuatan Material Bahan	Kecepatan Pemarutan	Kapasitas Pemarutan	Ketajaman Mata Pisau Parut	Dimensi	Daya Tampung Hasil Parut	Efisiensi Waktu	Kompetitor 1	Kompetitor 2
Mengoptimalkan Fungsional Alat	7	○	○	○	○	○	○	○	+	+
Hasil Ukuran Pepaya Yang Telah Dipotong Sesuai Dengan Mata Pisau	10		○	▲	○	▲		▬	−	+
Kepentingan Alat Dalam Proses Produksi	10	▬	○	▲	▲	○	▲	○	+	+
Pengoperasian Alat Agar Mudah Digunakan	9		▲	○	▲	▲	▬		−	−
Keseragaman Hasil Potongan Yang Dihasilkan Alat	9		○	▬	○				+	−
Kenyamanan Alat Saat Digunakan	10	▬	▲	▲	▲	○	○	▲	−	−
Mengoprasionalkan Alat Tanpa Menggunakan Banyak Tenaga Manusia	10	○		▲		○	▲	▲	−	−
Meningkatkan Keamanan Dalam Mengoprasionalkan Alat Saat Bekerja	10	○	○	▬	○	▬	▬	○	−	+
Nilai Kepentingan		29	39	32	45	43	26	34	25	28

Figure 7.

From the QFD results, the technical response scores were 29, 39, 32, 45, 43, 26 and 34. The highest score, 45, indicates that the sharpness of the blade of the young papaya grater is very efficient, able to simplify the process, and appropriate.

4.3 Concept Development

The concept was developed through an assessment of product specifications and design alternatives, based on the results of the QFD analysis. The main components used in this tool include: angle iron, dynamo, and bolts.

4.4 Product Concept Selection

After compiling several alternative concepts, concept selection was carried out using the concept screening method. There were 8 assessment criteria, which were scored with the symbols + (high) and - (low). The concept with the highest score was selected to proceed with the concept design.

4.5 Final Specification of Design Concept

The final concept of this tool focuses on increasing productivity through accelerating the process of grating young papaya using an electric dynamo. It is also easy to clean to prevent corrosion. The final specifications were based on data analysis from QFD

as well as customer feedback. The tool is made with a frame of 2 mm thick angle iron.

From the QFD above, we will design a vertical papaya grater design using software (SOLIDWORKS).

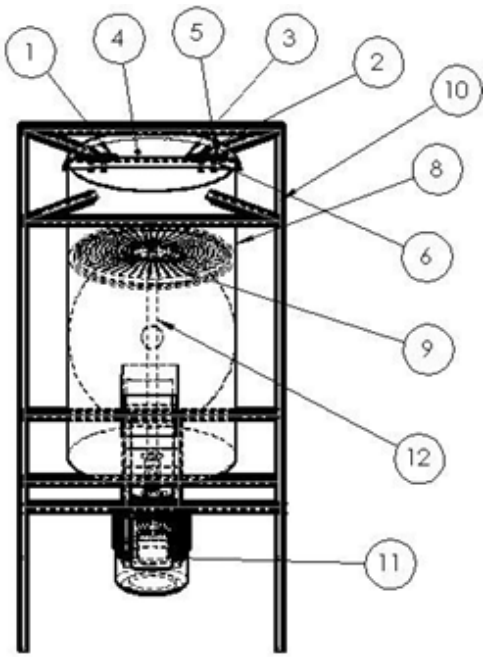


Figure 8. Specifications of the Grater

1. Right hinge function: to open and close the grater tube
2. Left hinge function: to open and close the grater tube
3. Axis function: to move the blade
4. Close the grater tube function: as a protector so that papaya is not scattered out
5. HBOLT 0.2500-28x1x1-N function: as a connection or mechanical installation
6. HJNUT 0.2500-28-D-N function: locking the position of other bolts or nuts
7. HHJNUT 0.2500-20-D-N function: as a lock nut used in conjunction with the main nut
8. The grated tube functions: as a container or place to hold the grated material.
9. 30 cm blade function: as the main tool that crushes or grates papaya into small or fine components.
10. Frame function: as a support and support for all machine components, provides additional strength, and reduces vibration during the grating process.
11. Dynamo function: converts electrical energy into mechanical energy that moves the engine parts.
12. The shredder shaft functions: as the main component that forwards the rotation from the motor to the shredder (blade).

Table 1. Design Optimization

Dynamo	Drum	Design Optimization	Using US
High productivity and requires little compressive Power	A place for harvesting and also plays an important role in maintaining the safety factor	Optimizes design to be more practical and high quality	Simplify the process

The table above shows the design optimization of the tool design. Where there is a frame that ensures the parts needed in the tool become more robust and where this design process plays an important role in terms of safety when operating the tool.

The results of the analysis show that competitor 1 has an importance value of 25 and competitor 2 has an importance value of 28. The sharpness of the grater blade has the highest importance value of 45, the dimensions have an importance value of 43, the speed of grating has an importance value of 39, time efficiency has an importance value of 34, grating capacity has an importance value of 32, the strength of the material has an importance value of 29 and which has the lowest importance value, namely the tamping power of the grated results, namely 26. From the QFD results the designed tool has a higher importance value than competitor 1 and competitor 2, this shows that the young papaya grater is very efficient, able to simplify the process, and appropriate.

CONCLUSION

By using the QFD method, the research has produced a design design for a papaya grater machine with a vertical model with a horizontal cutting knife position that considers important aspects needed by consumers. From the results of the analysis it can be concluded that a sturdy frame is needed to ensure that the engine components can be durable and can also reduce the risk of work accidents for operators who run it. The resulting design is optimal as evidenced by the value score in HOQ which is better than other competitors.

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