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Design of Biomass Stove Using the Quality Function Deployment (QFD) Method

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ABSTRACT

The design of the furnace used by the community is still very simple so that the combustion efficiency is still low. This study aims to design and test the performance of a wood stove based on the wishes and needs of the community. This study uses a descriptive design. The sample of this research is 50 respondents. The measuring instruments of this research are questionnaires and field observations. The method in this study uses the Quality Function Deployment (QFD) method in analyzing the wood stove production design and the House of Quality matrix is used in making the design to determine the characteristics of the community. The wood stove design used is two wood stoves. In the manufacture of this biomass furnace using mild steel material. The results showed that two wood stoves and one wood stove produced a faster boiling time than one wood stove, namely 4 minutes 52 seconds for two wood stoves, while for one wood stove it took 5 minutes 31 seconds. The difference in time obtained from these two tools is 39 seconds. The results of this study indicate that two wood stoves are more effective than one stove. This study recommends that people can use wood fuel when cooking, so it is easier than one biomass stove.

KEYWORDS: *Biomass stoves, Quality Function Deployment (QFD), House of Quality (HOQ).*

1.0 INTRODUCTION

Initially, rural communities used wood-fired stoves for cooking. Over time, people began to switch from using stoves to using kerosene-fired stoves. The use of kerosene continues to be carried out to meet daily cooking needs. However, in 2007, the government of Indonesia issued a policy regarding the conversion of kerosene to gas. As a result of the conversion policy, the distribution of kerosene became rare and very difficult to obtain. This forces people to use gas to fulfill their daily needs. Even so, the government has faced several obstacles in realizing the kerosene conversion program to LPG gas. These obstacles include the community still having difficulty accepting the conversion program because the community is worried about leaks in the LPG cylinder regulator hose, LPG cylinder explosions, and the uneven distribution of LPG cylinders, causing a shortage of LPG [1].

The scarcity of LPG gas also occurs in Kayu Ara Permai village, Sungai Apit District, Siak Regency, Riau Provice, Indonesia. Based on observations made in the village, local people can overcome the shortage of LPG gas by reusing wood as fuel to meet their cooking needs. This is in accordance with rural natural resources where there is still a lot of wood. Therefore, the reuse of wood-fired stoves is still favored by the community to meet their household needs.

Utilization of biomass waste is an alternative energy source that is very useful for reducing people's dependence on fuel oil (BBM) [2]. The stove design used by the community is still very simple so that the combustion efficiency is still low, which is only around 5 to 10% [3]. This statement is supported by research [4] which examined the performance of rocket stoves with wood pellets and *sangon* wood as fuel. This stove is in the form of a rocket made of iron pipes like a chimney. The use of a rocket burner can significantly increase combustion and displacement efficiency. The working principle of the rocket stove requires a small amount of firewood but produces optimal heat.

The phenomenon of the problems above shows that people still want and need to use wood as fuel. This made the researchers interested in designing and re-modifying the wood stoves used by the community. In this case the researchers designed and built a biomass stove based on the wishes and needs of the community using the method Quality Function Deployment (QFD).

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2.0 FUNDAMENTAL THEORY

2.1 Fuel

Fuels are materials used in the daily combustion process; fuel is very necessary for daily needs. Fuel has become a necessity for humans, while the supply of fuel in Indonesia is dwindling. The main requirement for the combustion process is the availability of fuel that mixes well with air and the combustion temperature is reached. The fuel used can be classified into three groups, namely liquid, gas and solid fuels [5].

2.2 Stove

A pottery stove is a tool made of clay which is shaped and then burned to make useful tools to help human life. Based on the research results, prehistoric pottery is estimated to be contemporaneous with the farming period. Pottery itself is used as household utensils. Several types of stoves based on their fuel (biomass), are as follows: Firewood and Charcoal stove, Sawdust stove, Liquid stove, Coal Briquette stove [6-9].

2.3 Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a structured method in product development that allows the product development team to clearly define all the wants and needs of consumers and then evaluate each product or service capability offered systematically to meet consumer needs [10][11].

The QFD process begins with hearing the voice of the customer and then continues through 4 phases namely, product planning, product design, process planning and production planning [10][12].

2.4 Matrix House of Quality (HOQ)

The process in QFD is carried out by compiling one or more matrices called The House Of Quality. This matrix explains what are the needs and expectations of customers and how to fulfill them [10],[13]. The matrix called House Of Quality in general can be seen in Figure 1 and the House Of Quality is illustrated in Figure 2 [10].

3.0 RESEARCH METHODOLOGY

This research method provides an overview of the design of a biomass stove using the Quality Function Deployment (QFD) method, which includes procedures and steps to be carried out in the research. The flowchart of the research conducted can be seen in Figure 3.

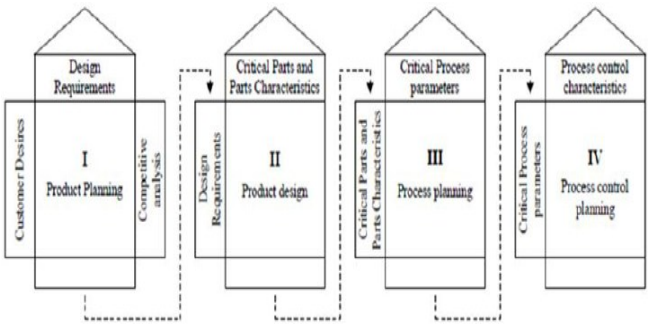

Figure 1: Matrix of House Of Quality [10]

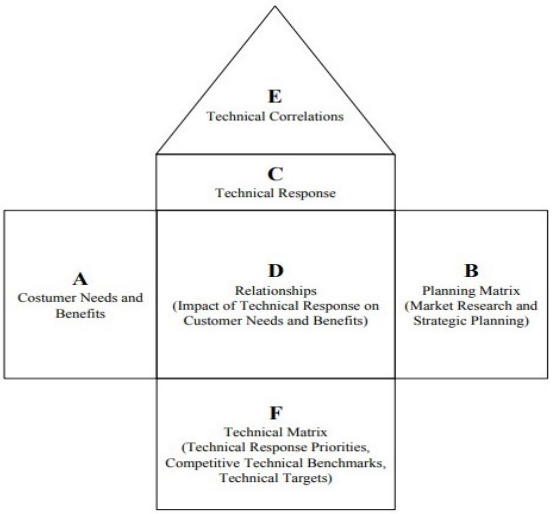

Figure 2: House Of Quality (HOQ) [10]

From the formulation of the problem that occurred in the community, then was carried out by compiling a House of Quality (HOQ) based on the phases of the Quality Function Deployment (QFD) method. In the process of making a House of Quality required to make a questionnaire. The interviewing customers were the people who use traditional stoves in Kayu Ara Permai Village, Sungai Apit District, Siak Regency, Riau Province, Indonesia. The stages in preparing the HOQ for this research can be seen in Figure 4.

In processing the questionnaire data there was processing of validity and reliability tests of the value of the interest or priority data that has been taken. The validity test is used to measure the validity or validity of a questionnaire. A valid questionnaire means that the measuring instrument used to obtain the data is valid. Valid means that the questionnaire can be used to measure what should be measured. Valid indicates the degree of accuracy between the data that actually occurs on the object and data that can be collected by the researcher. This validity test was carried out after obtaining data from distributing questionnaires in the community. The validity test in this study used the correlation product moment formula with the help of SPSS 25.0. To find out whether the questionnaire is used valid or not, the r count is indicated by the magnitude of the product moment table r. The validity test criteria: if r count > r table, it can be said to be valid and if r count <r table, it can be said to be invalid.

The reliability test is used to test the consistency of measuring questionnaire data, which be included in the Quality Function Deployment method to be used as a reference in research. At this stage the validity test was seen for its consistent value of questionnaire data processing. After obtaining the validity of the data from the questionnaire items, the reliability test was then carried out using SPSS 25.0 software. The reliability test of a questionnaire has several provisions for Cronbach's Alpha value if alpha > 0.90 then reliability is perfect, if alpha is 0.70 - 0.90 then reliability is high, if alpha is 0.50 - 0.70 then reliability is moderate, and if alpha < 0.50 then reliability is low.

The product concept development was carried out by researchers based on the information contained in the HOQ. The development of the tool planning concept refers to the characteristics that have the highest weight so as to produce

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several biomass of wood stove concepts. Product design was made based on information from the product concept and size based on provisions on existing wood stove quality standards so that later it can be used according to user needs.

After the product has been made, the next step is testing the product. The purpose of this trial was to determine the suitability of the finished product with the specified size, specification and design. This test was carried out by comparing the performance of existing stoves in the community. This performance was evaluated by comparing the time of boiling water, the amount of fuel used, and the remaining fuel produced.

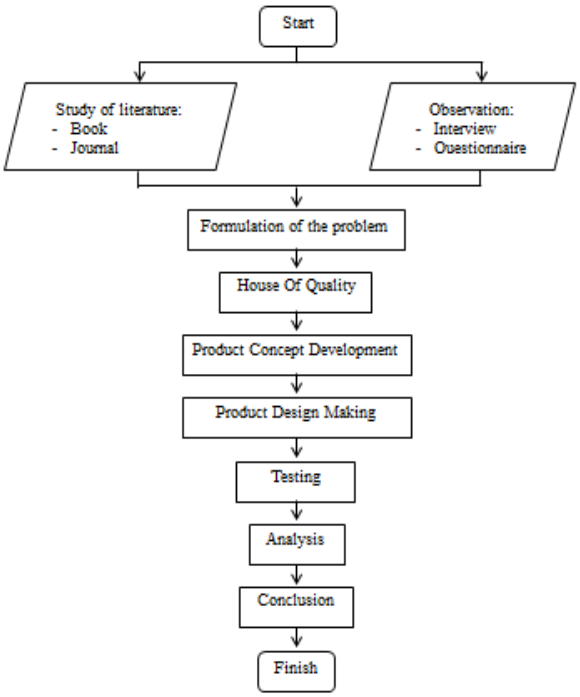

Figure 3. Flowchart of research

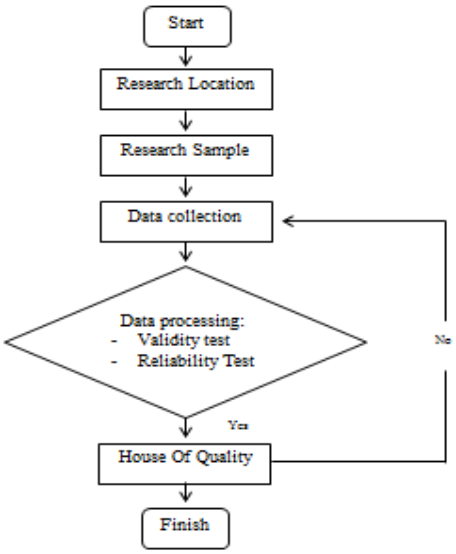

Figure 4: Flow proposed the Quality Function Deployment

4.0 RESULTS AND DISCUSSION

Research on the design of biomass stoves using the Quality Function Deployment (QFD) method, which was conducted in Kayu Ara Permai Village, Sungai Apit District, Siak Regency to 50 respondents who still use wood-fired stoves.

4.1 QFD Method Identification Results

The results of the validity and reliability tests are entered into the House of Quality matrix to obtain the required attributes for a biomass stove. This stage is the process of entering the data that has been obtained into the House of Quality which is then analyzed so that later it can be applied properly. In this study, researchers used a data analysis method, namely Quality Function Deployment (QFD) that can be seen in Figure 5.

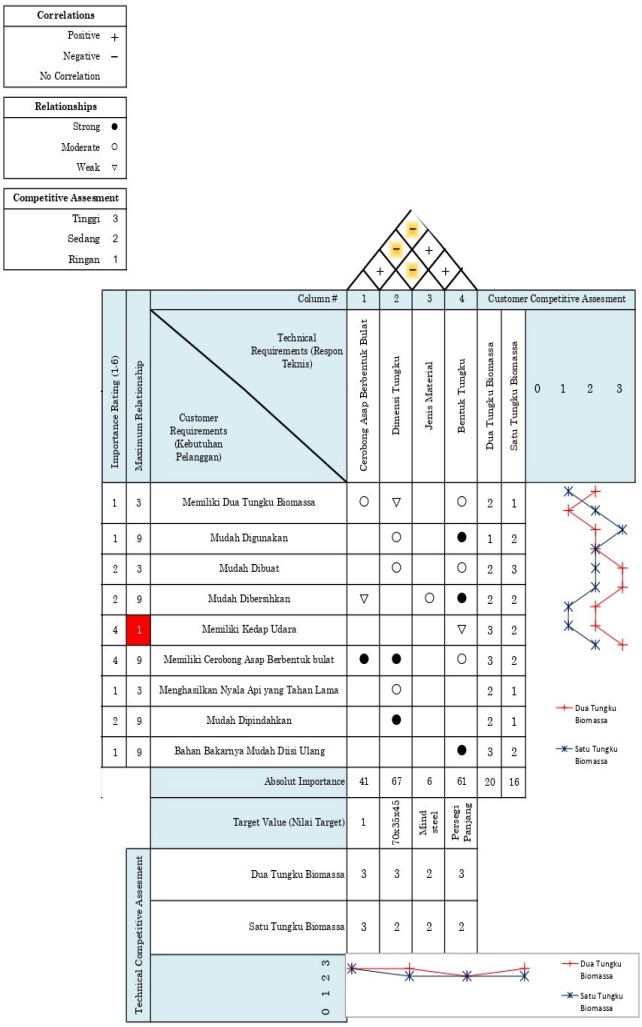

Figure 5: Processing House of Quality

4.2 Wood Stove Product Planning Concept Development

The development of the product planning concept in the design of this wood stove was based on an analysis of the House of Quality (HOQ) or the second quality house from the community's interest. Product specifications were based on a survey of people's needs and wants.

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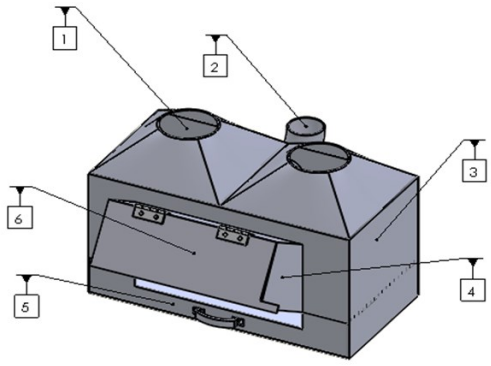
4.3 Product Design Making

The product concept planning development from one conventional biomass of wood stove to biomass wood stove. This furnace has a shape that was much larger than a conventional stove. However, the height of this stove can be adjusted to the wishes and needs of the community. Based on the interview results, it was found that the community felt more comfortable with the conventional stove height, which was 45 cm. This statement is in accordance with the results of research [14], which stated that the size of stoves in the community is 20-45 cm. If it is more than 45 cm then it can be said to be a jar and no longer said to be a furnace.

This stove has a simple shape and easy to use, which was 45 cm high, and has a large filling chamber. Hence, that more fuel was used and it was more optimal in the combustion process. The combustion chamber for wood burning has also been expanded to allow more air to penetrate and create an optimal combustion process. The design of the biomass of wood stove is shown in Figure 6.



1. Fire funnel
2. The chimney
3. Combustion chamber
4. Fuel funnel
5. Ash disposal box
6. Charcoal filter

Figure 6: The wood stove design proposed

4.4 Result of Product Testing

Biomass stove testing wass carried out to see the optimal fire and the material elasticity of the stove. The test was carried out by conducting an experiment of 1 liter of water, boiled at 100°C with a fuel capacity of 1.5 kg of tree logs. Next, compare the test with a biomass wood stove that has one burner with the same fuel capacity, water and wood. From the comparison obtained, it can be seen the time needed for one wood stove and two wood stoves to boil 1 liter of water at a temperature of 100°C, and the amount of fuel used to boil the water until it was boiled. The result of comparative data for each of the biomass stoves and gas stove, that can be seen in Table 1.

From the data in Table 1, it can be compared the time between two biomass wood stoves with one biomass wood stove. First, the fuel used between two biomass wood stoves and one biomass wood stove was the same as using 1.5 kg of biomass wood fuel. Two biomass wood stoves were consumed as much fuel as 0.9 kg of wood. Then for one biomass wood stove, it consumed as much as 0.8 kg of biomass wood as fuel. Then, two biomass wood stoves and one biomass wood stove resulted in a faster boiling time than one biomass wood stove, namely for 4 minutes 52 seconds for two biomass wood stoves. Whilst, the boiling water for one biomass wood stove produced 5 minutes 31 seconds. It can be concluded that two biomass wood stoves were more effective in the cooking process than one biomass wood stove. This can be seen from the significant time difference of 39 seconds between two biomass wood stoves and one biomass wood stove**.**

Table 1. Test comparison data

No	Type of stove	Object	Initial fuel capacity	Remaining fuel	Amount Used	Temperature	Time
1	2 wood stove	1 L water	1.5 Kg wood	0.6 Kg	0.9 Kg	100°C	4 minutes 52 seconds
2	1 wood stove	1 L water	1.5 Kg wood	0.7 Kg	0.8 Kg	100°C	5 minutes 31 seconds

5.0 CONCLUSION

The results obtained from the House of Quality (HOQ) data indicate that the development of the one-stove and two-stove design concepts is the optimal design alternative for the biomass stoves. The alternative design of two biomass wood stoves from the test results that is easy to make and easy to operate.

Based testing result revealed the time difference between one biomass wood stove and two biomass wood stoves, which was 39 seconds. This can be seen from the comparison between the two biomass stoves and one biomass wood stove. The results of wood stove testing conducted between one biomass wood stove and two biomass wood stoves can be concluded that two biomass wood stoves were more effective than one stove.

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