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Design of a Drying Machine for Charcoal Bricks to Improve Cost Efficiency in Production and Profitability using the Quality Function Deployment Method

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ABSTRACT

The charcoal briquette MSME in Gedangan Subdistrict, Sidoarjo Regency, is a business engaged in the production of alternative energy based on coconut shell waste and sawdust. The production process involves burning, grinding, mixing adhesives, molding, and drying. However, based on observations, around 30% of raw materials are not optimally utilized because they become waste in the form of ash and coarse charcoal. This condition causes low production efficiency and increased operational costs. In addition, the capacity of the existing charcoal briquette drying machine is still limited, the molding results are often inconsistent, and the durability of the machine material is relatively low. This research aims to design a more efficient charcoal briquette drying machine that meets the needs of MSMEs using the Quality Function Deployment (QFD) approach. This method emphasizes translating user needs into technical product requirements, so that the machine design not only pays attention to technical aspects, but also meets user expectations. The design results are expected to increase productivity, reduce raw material waste, produce briquettes with uniform quality, and reduce production costs. With the design of a charcoal briquette drying machine based on QFD, Charcoal Briquette MSMEs are expected to maintain production continuity and become an example of the application of appropriate technology in processing biomass-based alternative energy.

1. Introduction

The development of Micro, Small, and Medium Enterprises (MSMEs) plays a strategic role in supporting local economic growth, job creation, and sustainable development, particularly in rural and semi-urban areas. In recent years, increasing attention has been directed toward MSMEs that adopt environmentally friendly production practices and utilize waste-based raw materials, as these businesses contribute not only to economic value creation but also to environmental conservation and circular economy initiatives. One of the promising sectors in this context is the production of alternative energy derived from biomass waste.

The charcoal briquette MSME is a business engaged in the production of alternative energy located in RT.4/Rw.4, Ngudi, Punggul, Gedangan District, Sidoarjo Regency, East Java. The main focus of this MSME is on the processing of coconut shell waste into environmentally friendly briquette charcoal. This MSME focuses on the utilization of raw materials from coconut shell waste which has high heat quality and is in great demand by household consumers and small industries [1], [2]. The utilization of coconut shell waste as a primary raw material is considered highly potential because it is abundantly available, renewable, and capable of producing briquettes with high calorific value and low emissions compared to conventional charcoal.

In the Charcoal Briquette MSME, the production process begins with the processing of raw materials in the form of coconut shells and sawdust available from agricultural waste and the wood industry. The initial stage begins with the combustion process (carbonizing) to produce charcoal, then continued with grinding into a fine powder, mixing with natural adhesives, molding into briquette forms, and finally drying to a low water content to produce optimal combustion quality [3]. The production cycle of this briquette charcoal is usually carried out periodically every month, so that the MSME can maintain the continuity of product availability for the market. With a controlled process, the resulting briquettes have a

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uniform shape, high burning power, and are environmentally friendly. The charcoal briquette production process is shown in Figure 1 below.

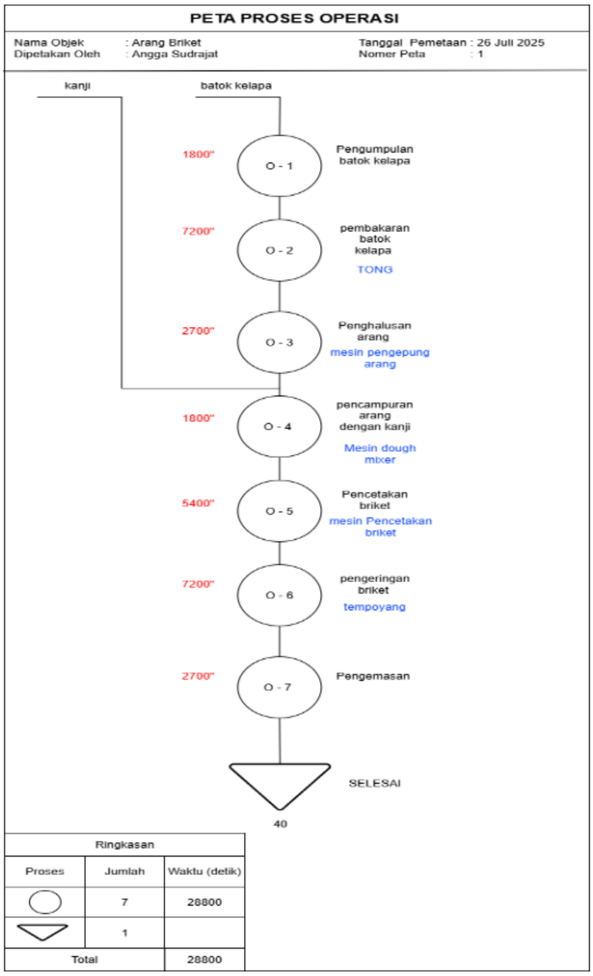

Figure 1 Operation Process Map

Based on interviews with sources at the MSME, the charcoal briquette production process is carried out periodically every month. The following production and sales data for four months are shown in Tables 1, 2, and 3. The MSME owner sets the selling price of charcoal briquettes at IDR 20,000 per kilogram for the local market, with the price subject to adjustment if there is large demand from distributors or industrial consumers.

Table 1
Sales Data

Month	Total Sales		Price Per Kg	Total Sales	
March 2025	1200	kg	Rp 20.000,00	Rp	24.000.000,00
Apr-25	1300	kg		Rp	26.000.000,00
May 2025	1200	kg		Rp	24.000.000,00
June 2025	1800	kg		Rp	36.000.000,00
Total				Rp	110.000.000,00

Table 2
Raw Material Requirements Data

Month	Production day	Daily production	Total production
March 2025	25 day	40 kg	1000 kg
Apr-25	24 day	46 kg	1104 kg
March 2025	25 day	42 kg	1105 kg
June 2025	26 day	65 kg	1690 kg

Table 3
Unused Raw Material Data

Month	Production Day	Production per Day	Total Production (kg)	Raw Material Estimation (kg)	Unused Remainder (30%)
March 2025	25 day	40 kg	1.000	1300	300
April 2025	24 day	46 kg	1.104	1435	331
May 2025	25 day	42 kg	1.105	1437	332
June 2025	26 day	65 kg	1.690	2197	507

Tables 1–3 present sales data, raw material requirements, and unused raw material quantities, respectively. The presence of unused raw materials, which reaches approximately 30% of the estimated input, indicates inefficiencies in the current production system. This condition not only increases production costs but also reduces the overall profitability of the MSME. Therefore, efforts to improve production efficiency and reduce material waste are critically needed.

In this study, researchers designed a charcoal briquette making machine using the Quality Function Deployment (QFD) method. This machine is designed to help charcoal briquette MSMEs improve production efficiency, reduce waste, and ensure more consistent product quality. This tool is expected to not only benefit charcoal briquette MSMEs but also serve as an example of appropriate technology solutions for other briquette processing MSMEs in the surrounding area.

The application of the Quality Function Deployment (QFD) approach in the design of the charcoal briquette making machine aims to ensure that the product developed truly meets the needs and expectations of users, namely charcoal briquette MSMEs [5], [6], [7]. The initial step in this method begins with collecting customer feedback, typically through interviews or direct field observations. This information is then translated into technical product requirements during the planning stage [8]. By applying this method, machine development focuses not only on technical aspects but also on maximizing production output to meet consumer demand. Based on a benchmarking analysis of existing charcoal briquette making machines, several shortcomings were identified, particularly in terms of material durability and production efficiency. Print results were often inconsistent and required longer processing times if production capacity was increased. This indicates that the previous machines did not fully meet user expectations, especially for MSMEs that require large quantities of briquettes, good quality, and low production costs. Therefore, a more efficient charcoal briquette making machine design is needed, capable of minimizing operational costs, producing uniform prints, and increasing profits for MSMEs producing charcoal briquettes.

2. Research methods

Conducting direct observations and data collection on the owner and workers in the charcoal briquette printing section to identify the shortcomings and obstacles faced by the MSME. Conducting analysis to identify problems involving a review of initial findings. Aims to create a charcoal briquette printing tool that can reduce production costs [9]. The research flow is shown in Figure 2.

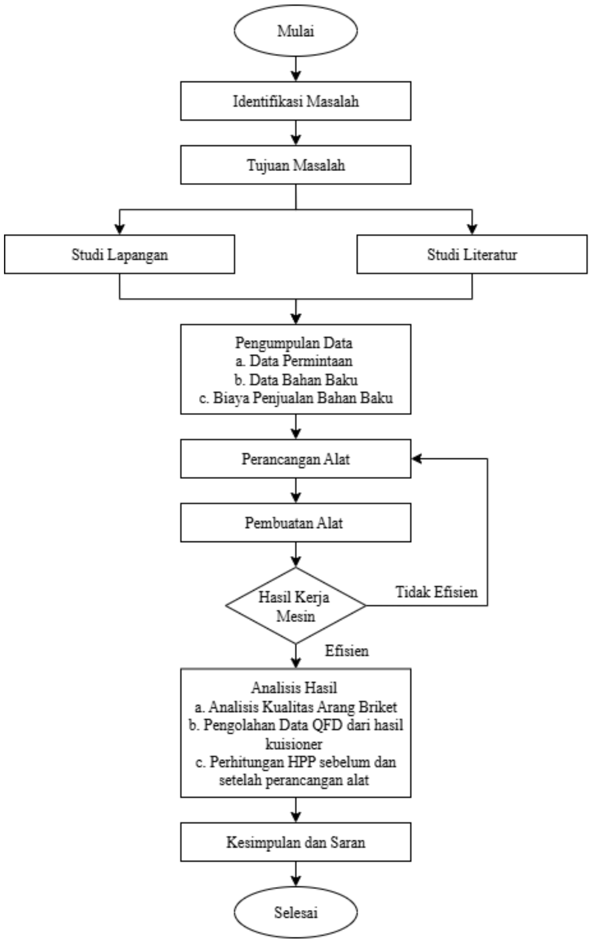

Figure 2 Research Stages

2.1 *Field and Literature Studies*

Conducting direct observations at MSME locations to understand the charcoal briquette production process, including the burning, grinding, mixing, molding, and drying processes. This stage also includes interviews with owners and workers to identify deficiencies, operational obstacles, and user needs related to the charcoal briquette molding machine. In addition, a literature review was conducted through books, journals, research reports, and other scientific sources relevant to product design, Quality Function Deployment (QFD), and production cost efficiency (COGS). The results of the literature review serve as a theoretical basis for formulating appropriate solutions to MSME problems.

2.2 *Data Collection*

Data collection was conducted through direct observation and structured interviews with production workers. The data collected included:

a. Demand data, to determine market demand for briquette charcoal.
b. Raw material data, such as coconut shell requirements, adhesives, and other resources.
c. Cost of selling briquette charcoal, including selling price, operational costs, and production costs.
d. This data serves as the basis for calculating production capacity, estimating costs, and guiding machine design.

2.3 *QFD Stages*

Conducting research conclusions from research results using the QFD (Quality Function Deployment) method. The following are the stages of implementing the QFD method [10], [11], [12]:

a. Identifying Customer Needs (Customer Requirements or Voice of Customer): Collecting needs and complaints from previous machine users through interviews and observations.
b. Determining the Weight or Importance of Customer Needs: Prioritizing customer needs based on their urgency and impact on product quality.
c. Translating Customer Needs into Technical Characteristics: Transforming customer needs into technical specifications that the machine must meet.
d. Benchmarking Against Competitor Products: Comparing existing briquette presses on the market to identify their strengths and weaknesses.
e. Calculating Product Objectives: Determining the technical targets to be achieved by the new machine design, such as increasing capacity or improving print quality stability.
f. Determining Technical Responses: Determining the technical actions required to achieve the established objectives.
g. Interaction Matrix: Analyzing the relationship between customer needs and technical characteristics to prioritize improvements.
h. Creating Concept Development: Creating a machine design concept based on the analysis results of the QFD matrix to produce an optimal design.

2.4 *Tool Design & Tool Drawings*

At this stage, a charcoal briquette printing machine is designed, complete with all mechanical and additional components needed to improve machine performance. The design is visualized through technical drawings to ensure clear specifications and allow for production according to plan [13]. Once the design is approved, the tool is fabricated based on the technical specifications. Next, the tool will be field-tested to observe production effectiveness, print quality, and user comfort.

2.5 *Tool Making & Tool Testing*

The tool was developed with adjustments from the previous machine, primarily to achieve greater and more efficient production capacity. After the tool was completed, operational trials were conducted at MSMEs. If any discrepancies were found, the machine was evaluated and improved until its performance met user expectations. This process continued until an agreement was reached between the researchers and the MSME that the tool was working optimally and was ready for use in production [14].

3. Results and Discussion

This section discusses the results and analysis of the study discussed in the paper related to the design of a charcoal briquette drying machine to increase production cost efficiency and profitability using the QFD method.

3.1 Customer Interest Level

Based on both questionnaire data (open and closed questionnaires), this study obtained quantitative data supplemented with a degree of importance. This degree of importance serves to determine the priority of each customer need which will later become the basis for compiling the House of Quality. Before conducting further analysis, the following is a recapitulation of the attribute values of the level of importance that have been obtained from all respondents [12]. A total of 30 respondents involved in filling out the questionnaire consisted of parties directly involved in the production and distribution of charcoal briquettes. These respondents included 5 owners of charcoal briquettes MSMEs, 15 production workers experienced in the drying process and machine operation, and 10 distributors and collectors who understand product quality and market needs. This composition of respondents ensures that the data obtained reflects operational needs in the field comprehensively, so that the resulting customer importance attributes represent the perceptions of various stakeholders in the briquettes production and distribution chain. This data summary is shown in Table 4, which serves as the basis for determining which attributes are considered most important by customers.

Table 4
Results of the Summary of Interest Attributes

No Respondents	Attribute Variables								Total
	1	2	3	4	5	6	7	8	
1	3	4	3	4	4	4	3	3	28
2	1	1	2	1	4	3	2	2	16
3	4	4	4	3	1	3	2	2	23
4	3	4	3	3	3	4	4	4	28
5	4	4	4	2	4	4	3	3	28
6	3	3	3	4	4	4	4	4	29
7	4	3	3	4	3	3	4	4	28
8	4	2	4	4	4	4	3	4	29
9	2	2	4	4	3	4	4	4	27
10	4	2	4	4	4	4	2	3	27
11	3	4	4	3	3	4	4	3	28
12	4	2	4	3	4	3	4	4	28
13	4	4	4	4	3	3	3	4	29
14	3	4	4	4	4	3	4	3	29
15	2	3	3	2	3	3	3	4	23
16	3	4	4	4	4	4	4	3	30
17	3	3	3	3	4	4	3	4	27
18	2	4	3	4	3	3	2	1	22
19	1	4	3	4	4	2	2	3	23
20	3	3	3	2	2	4	2	3	22
21	4	4	3	4	4	4	4	3	30
22	2	2	2	4	4	4	3	3	24
23	3	3	3	1	2	2	3	2	19
24	2	4	4	4	3	4	4	4	29
25	4	3	4	3	4	2	4	4	28
26	3	3	4	3	3	3	3	4	26
27	4	4	3	3	3	4	3	3	27
28	3	3	3	1	1	3	3	3	20
29	4	4	4	3	3	4	4	4	30
30	4	4	3	4	3	4	3	4	29
Average	3.1	3.3	3.4	3.2	3.3	3.5	3.2	3.3	

3.2 Product Evaluation

At this stage, a product evaluation analysis is carried out on the charcoal briquette drying machine, both the machine to be designed and the comparison tool currently used by MSMEs [15]. This evaluation is important to determine the differences in characteristics, weaknesses of the old tool, and the potential for performance improvements that can be achieved through the new design. To provide a visual depiction of the shape and concept of the proposed tool, Figure 3 is shown below, which shows the design of the charcoal briquette oven to be made. This image provides an initial illustration of the tool design in terms of appearance and construction.

Figure 3 Charcoal Briquette Oven (to be made)

Next, as a comparative analysis, Figure 4 shows the charcoal briquette oven currently used by MSMEs. This comparative image serves to identify differences in features, capacity, and potential improvements that can be applied to the new design.

Figure 4 Charcoal Briquette Oven (comparison tool)

3.3 Customer Interest Level

To ensure that the design of the charcoal briquette drying machine truly meets user needs, an identification of the level of customer importance was carried out on various design attributes that had been formulated [16], [17]. This analysis provides an overview of which aspects are considered most crucial by respondents, so that it can be used as a basis for determining product development priorities. A recapitulation of the level of customer importance is presented in the following tables, Table 5 and Table 6, as a basis for further calculations in the QFD method.

Table 5
Item Specifications

Items	Specification
Frame Material	C80 Mild Steel Channel
Frame Cover Material	Mild Steel #1.2mm
Support Material	Elbow 50 Mild Steel
Chain Mount Material	Elbow 40 Mild Steel + Napatoc plate #2 mm
Conveyor Pipe Material	Ø19 mm SS304 pipe
Door Material	Outside Mild Steel #1.2 mm; Inside Mild Steel #1.2 mm + Rock Wool
Shaft Material	Ø1.5” Mild Steel
Motor Mount Material	Mild Steel #10–12 mm
Heat Air Output Material	SS201 pipe Ø165 mm; SS201 Ø1.5” pipe
Hot Air Guide Tongue Material	SS304 #1.5mm

Table 6
Drive Motor Item Specifications

Items	Specification
Drive Motor	- Electric Fukuta Brand Motor - 3HP, 220/380 V, 50 Hz - 1440 rpm - SKT Brand Gear Box - Type: SKT – E 40

3.4 *Quality Function Deployment*

Degree of importance of the attributes of the charcoal briquette dryer tool degree of importance is used to determine the priority position of each consumer need. To obtain the priority of customer needs in a more structured manner, the QFD method is used which allows each attribute to be evaluated based on its level of importance. Before the calculation is carried out, these attributes are analyzed through a process of determining the degree of importance using the Relative Importance Index (RII) in Table 7. This calculation serves to identify which attributes should be the main focus in the development of the charcoal briquette dryer tool [18], [19]. The RII calculation formula and the results of the degree of importance value are presented in the following table as a basis for the next stage of analysis. The degree of importance value is calculated using the following formula:

$$RII = \frac{accumulated\ sum\ of\ each\ attribute}{total\ number\ of\ respondents} \ldots\ldots (1)$$

Table 7
Degree of Importance Values

VOC Number	Attribute	RII
1	Design	3.1
2	Product quality	3.3
3	Product lifespan	3.4
4	Product dimensions	3.2
5	Production capacity	3.3
6	Product safety	3.5
7	Product price	3.2
8	Maintenance	3.3

The score indicates the level of one attribute relative to another. The first-ranked attribute is "Ergonomics," and the last-ranked attribute is "Ease of Operation."

Tabel 8
Score Evaluation

No.	Attribute	Evaluation Score	Target Value
1	Design	4	4
2	Product quality	4	4
3	Product lifespan	4	3
4	Product dimensions	4	4
5	Production capacity	4	4
6	Product safety	4	4
7	Product price	2	3
8	Maintenance	4	3

Description: Evaluation Score = Comparative Tool/Competitor
Target Value = Tool created

Based on the evaluation results in Table 8, each attribute was compared between the benchmark and the designed tool. However, to obtain a more comprehensive picture of each attribute's contribution to customer needs, further calculations were required, including Importance Ratio (IR), RII values, and priority weights. These calculations yield a final importance level, which serves as the basis for determining which attributes should be prioritized in the tool development process. The complete evaluation results for all these parameters are presented in Table 9 below.

Table 9
Score Evaluation Results

No.	Attribute	Evaluation Score	Target Value	IR	RII	Weight	Weight
1	Design	4	4	1	3,1	3,1	0,13
2	Product quality	4	4	1	3,3	3,3	0,14
3	Product lifespan	4	3	1,3	3,4	4,5	0,20
4	Product dimensions	4	4	1	3,2	3,2	0,14
5	Production capacity	4	4	1	3,3	3,3	0,14
6	Product safety	4	4	1	3,5	3,5	0,15
7	Product price	2	3	0,7	3,2	2,1	0,09
8	Maintenance	4	3	1,3	3,3	4,29	0,19
	Total				26,3	23,07	1,18

3.5 *Technical Parameters*

Technical parameters are the result of translating consumer desires into measurable technical language to determine the target values to be achieved. The technical parameters used can be seen in Table 10 below.

Table 10
Technical Parameters

No.	Attribute	Technical Parameters	Information
1	Product Design	Ease of use	Operates without special skills
2	Product Quality	Effectiveness of the device	Takes 2-8 hours per process
3	Product Lifespan	Easy and quick to clean	Reduced maintenance
4	Product Dimensions	Component cleanliness	Regular cleaning prevents equipment damage
5	Production Capacity	Temperature	Maintains temperature according to material specifications
6	Product Safety	Surface protection	Anti-rust coating paint
7	Product Price	Device price	Relatively affordable price
8	Maintenance	Heating type and power	Balanced power heater and automatic control maintain temperature stability throughout the drying process.

3.6 Technical Parameters

The House of Quality explains what consumers want or need and how to fulfill them. The House of Quality is created based on data processing from questionnaires and interviews conducted through to the interaction of technical parameters. The following is the final result of the House of Quality for the Charcoal Briquette Dryer. Through this process, each customer requirement is translated into technical characteristics that can be measured and controlled in the design process. The results of this integration are then summarized in a matrix to ensure all customer needs have been comprehensively considered. Figure 6 shows the final result of the House of Quality for the Charcoal Briquette Dryer.

The House of Quality (HOQ) results in Figure 6 demonstrate the overall relationship between customer requirements and the designed technical parameters. The HOQ matrix demonstrates how each requirement attribute, such as design, product quality, product life, production capacity, safety, price, and maintenance, is transformed into a measurable and controllable technical response during the tool design process.

Specifically, the relationship between customer requirements and technical responses is indicated by a correlation symbol. A positive correlation (+) indicates that improving a technical characteristic will improve customer satisfaction, while a negative correlation (-) indicates that inappropriate changes can decrease customer satisfaction. For example, the need for long product life has a strong positive correlation with technical parameters such as ease of cleaning and the selection of rust-resistant materials. Conversely, some attributes, such as product price, have a negative correlation with certain technical parameters, such as the addition of an automatic heating feature, making design balance crucial.

In addition, the HOQ also identifies technical parameters with the highest priority weight based on the weight values in Table 7. The parameters with the highest weight include product life (0.20) and maintenance (0.19), which means these two aspects are the most crucial factors for consumers. This is followed by safety aspects (0.15), product quality (0.14), production capacity (0.14), and product dimensions (0.14). This priority information serves as the basis for determining technical features whose quality must be ensured during design, such as the use of anti-rust materials, heater design with automatic temperature control, and stable temperature regulation during the drying process. Thus, the HOQ not only serves as a tool for mapping customer needs but also serves as a strategic guideline in technical decision-making. Through this interpretation, all customer needs are successfully translated into measurable technical specifications, which are then summarized in the concept development process in the next section.

3.7 Concept Development

Based on the House of Quality analysis results in Figure 6, each customer requirement attribute has been translated into technical specifications relevant to the function and purpose of the designed tool. The next stage is to compile the product concept, which is to summarize all the priority specifications resulting from QFD into a design concept that can be realized in the charcoal briquette dryer. The summary of these specifications is shown in Table 11 below as a basis for the detailed design process.

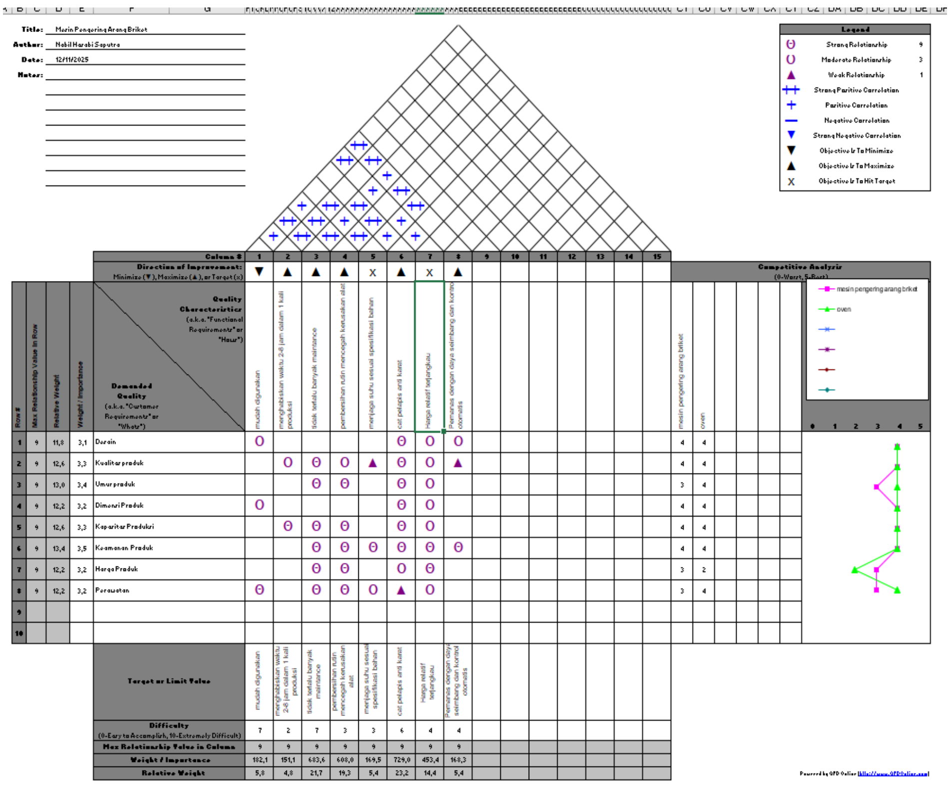

Figure 6 House of Quality

Table 11
Concept Development

No		QFD Product Specifications
1	Product Safety	Anti-rust coating paint
2	Product Lifespan	Reduced maintenance requirements
3	Production Capacity	Maintains temperature according to material specifications
4	Product Quality	Takes 2-8 hours per process
5	Maintenance Product Price	Balanced heating and automatic control maintain temperature stability during the drying process Relatively affordable price
6	Product Dimensions	Regular cleaning prevents equipment damage
7	Design	Operation without special skills
8	Product Safety	Anti-rust coating paint

3.8 3D Tool Drawing

After the product specifications are formulated through the QFD process and concept development, the next step is to visualize the device design in a three-dimensional model. This 3D visualization aims to provide a clearer picture of the shape, dimensions, and component configuration of the charcoal briquette dryer to be manufactured. A complete representation of the device design can be seen in Figure 7 below.

Figure 7 Tool Image

3.9 Cost Analysis

The implementation of the charcoal briquette drying machine designed in this study has been proven to provide production cost efficiency compared to the manual drying process previously used by MSMEs. Based on a comparison of key cost components, such as fuel consumption, drying duration, and production capacity per cycle, the use of the drying machine can reduce energy requirements and accelerate the process time, resulting in lower operational costs per kilogram of briquettes. Furthermore, the increased drying capacity contributes to lower fixed costs per unit of product, which directly increases profit margins. This efficiency also has an impact on improving business profitability, as reduced production costs are followed by an increase in daily output. Therefore, overall, the cost analysis shows that the use of the charcoal briquette drying machine provides significant economic benefits and supports the claim that this tool is able to increase production cost efficiency and profitability of MSMEs.

4. Conclusion

Based on the results of this study, the application of the Quality Function Deployment (QFD) method, specifically through the House of Quality analysis, resulted in a series of detailed technical specifications for a charcoal briquette drying machine. This design focuses on improving quality, operational efficiency, and reducing costs. Improved Quality and Efficiency: This machine is designed to significantly speed up the drying process, taking only 2 to 8 hours per cycle, much shorter than the natural drying method which takes 2 to 3 days. Accurate temperature control, this tool is equipped with a well-calibrated heating system and automatic controls to maintain a stable temperature throughout the drying process. Durability and price to ensure safety and a longer product life, the machine is coated with anti-rust paint. In addition, the design is made to require minimal maintenance and is offered at a relatively affordable price. Ease of use, this machine is designed to be easy to operate by anyone, even without requiring special skills or training. Overall, the design of the QFD-based charcoal briquette drying machine is expected to boost productivity, minimize raw material waste (by producing more uniform and high-quality briquettes), and have an impact on reducing production costs and increasing profits for charcoal briquette MSMEs.

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