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Productivity and Flexibility Improvement of Straw Mushroom House

Ivan Sujana[1*], Fitri Imansyah[2*], Noveicalistus H Djanggu[3]
[1]Industrial Engineering Department, Tanjungpura University, Indonesia
[2]Electrical Engineering Department, Tanjungpura University, Indonesia
[3]Industrial Engineering Department, Tanjungpura University, Indonesia

Email: [1]ivan.sujana@industrial.untan.ac.id, [2]fitri.imansyah@ee.untan.ac.id, [3]noveicalistus.djanggu@industrial.untan.ac.id

Abstract. This study aims to improve the productivity and flexibility of the mushroom house to increase the production of straw mushrooms. Determining the design of technical specifications and material requirements of the mushroom house is a process that is quite important in determining the success or failure of increasing straw mushroom production. QFD (Quality Function Deployment) is used to obtain the best design based on the needs of the mushroom farmers. The needs of the mushroom farmers are then translated through QFD into technical specifications. MCDM (Multi Criteria Decision Making) is used to determine the material for the frame and blanket of the mushroom house according to the technical specifications of the QFD. CRITIC (Criteria Importance Through Intercriteria Correlation) is one of the methods of MCDM that performs an objective weighting of the criteria. A mushroom house was built based on the technical and material specifications obtained from QFD and CRITIC. Tests were carried out by comparing the productivity and flexibility between traditional mushroom houses and designed mushroom houses. The peroductivity of the mushroom house includes cleanliness, stability in temperature and humidity, the rate of growth of straw mushrooms in media. Flexibility includes the ability to assembled and disassembled, easily mobilize from one place to another.

Keywords: Mushroom House; QFD; MCDM; CRITIC

1. Introduction

Straw mushroom is one of the cultivated mushrooms that has a selling value. In West Kalimantan, straw mushrooms can be bred in mushroom houses or grow wild on Oil Palm Empty Fruit Bunches (OPEFB) planting media. As one of the areas producing Crude Palm Oil (CPO), West Kalimantan has a fairly large area of oil palm plantations. Oil Palm Empty Fruit Bunches can be seen in Figure 1. Oil palm farmers take advantage of processed CPO in the form of OPEFB as a growing medium for straw mushrooms. Oil palm farmers generally breed straw mushroom in traditional mushroom houses. Traditional mushroom houses are built using frame materials derived from bamboo and wood. The roof and walls of the mushroom house were built using thin plastic materials, woven leaves, woven bamboo, and wood. The shape of the conventional mushroom house in Thailand is like a cottage made with cogon grass [7]. Traditional mushroom houses frame can be seen in Figure 2.

Figure 1. Oil Palm Empty Fruit Bunches (OPEFB)

The main problem that occurs in traditional mushroom houses, among others, is the relatively short service life of the mushroom house between 1 -2 years. Damage occurs due to the process of decay in the frame, roof, and walls made of organic materials. Mushroom houses must have high enough humidity, this condition causes physical buildings to easily decay. The thin plastic used to control humidity and lighting is damaged by wear and environmental factors. The floor of the mushroom house will become increasingly unsterile because of the humidity factor that makes the floor of the mushroom house muddy. Unsterile mushroom house conditions will affect the productivity of fungal growth because the growing media is overgrown by wild mushrooms. Maintaining proper environmental conditions for growth of mushrooms is as important as securing good substrates [8]. The supply of OPEFB as a planting medium in each farmer group is unstable, some areas have excess supply of planting media and there are areas that lack planting media. To meet the supply needs, the planting medium needs to be moved from one area to another. Media transfer activities lead to increased costs.

Figure 2. Traditional mushroom houses frame

To increase productivity and minimize costs, farmers need mushroom houses that can minimize some of these problems. To obtain a suitable design, the QFD method is needed as a tool to translate the needs of farmers into a technical design. Rapid changes in product functional requirements cause product life to decrease significantly. These circumstances place a premium on companies' ability to develop products in a timely manner. So far, the approach method for conducting the product design and development process has been developed in many fields. The QFD method focuses on consumer needs and coordination during the product production process. A QFD is a planning tool used to translate and ensure consumer needs are involved in design and production planning activities [4]. By using the QFD method, the needs of farmers will be accommodated because farmers are involved in the planning activities of mushroom house designs. Material selection is a very important part of the design. In an effort to choose a suitable material for the designed product, there are many factors that influence it, including the operational environment, production process, cost, and availability. With many influencing factors, a multi-criteria selection method (MCDM) is needed [3]. Product development has several stages, and the conceptual design stage is a very crucial part of the product development process. Errors at the design and material selection stages will lead to product failure and increased costs. CRITIC (Criteria Importance Through Intercriteria Correlation) is a part of MCDM that uses objective weighting against criteria [1]. QFD can be used to interpret consumer voices into technical specifications. MCDM is used to select the best design and material for the product. QFD and MCDM can be used together to ensure successful product development [5]. In addition to involving farmers in determining the design, material selection plays an important role in supporting the success of the mushroom house design. Material selection errors will have a negative impact in terms of cost and design failure.

2. Data Collection and Processing

2.1. QFD Data Collection

Users, who in this case are oil palm farmers, mushroom farmers, and rice farmers, are used as resource people in conducting interviews. Based on the results of these interviews, a questionnaire will be designed to identify the needs of mushroom houses that will be designed and built later. Farmers who have previously cultivated edible mushrooms first provide a statement regarding mushroom cultivation, and later the solution from that statement will be interpreted as a necessity. The user statements and their interpretations can be seen in Table 1.

Table 1. User Statement

No	User Statement	Intepretation of Need
1	The land and traditional mushroom houses that are used will become slums over time	Easy-to-clean mushroom house
2	The traditional mushroom house that still uses a wooden frame is damaged due to decay factors	Mushroom house frame is strong and sturdy
3	Mushroom house blankets do not consistently maintain light intensity, humidity, and temperature due to wear and tear factors	A strong and consistent mushroom house blanket maintains light intensity, temperature and humidity
4	The transportation cost of bringing in OPEFB planting media is quite high	Kumbung can be mobilized and brought closer to the supply
5	Limited land area that can be used to build kumbung and its supporting facilities	mushroom house is easy to disassemble and flexible to adjust the size of the land

2.2. QFD Data Processing

Priority requirements are used to determine the order of priority of the technical requirements of an attribute that will be applied to the designed tool. Priority needs are divided into two types, namely absolute importance and relative importance. Priority needs

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are then translated into a house of quality. The QFD priority requirements can be seen in Table 2.

Table 2. Requirement Priorities

No	Technical Requirements	*Absoulute Importance*	*Relative Importance*	Priority
1	Mushroom House can be disassembled and installed	131,24	18,96%	**1**
2	Using quality iron	48,03	6,94%	**9**
3	The connection between the frame is strong	69,82	10,09%	**5**
4	Using hollow iron	70,83	10,23%	**4**
5	Making connections between frames	85,77	12,39%	**2**
6	Mushroom house is well covered	36	5,20%	**10**
7	Using a quality tarpaulin	85,38	12,33%	**3**
8	Has air vents that can be opened and closed	53,93	7,79%	**7**
9	Mushroom house using thick and flexible tarpaulin	61,38	8,87%	**6**
10	Mushroom house using dark tarpaulin	49,8	7,19%	**8**

Starting from collecting the voice of customer data until it is processed into a quality function deployment, it can be built as a quality house or a house of quality (HOQ) from the mushroom house that will be designed. The following is a HOQ of the mushroom house that will be designed and built. The HOQ can be seen in Figure 3.

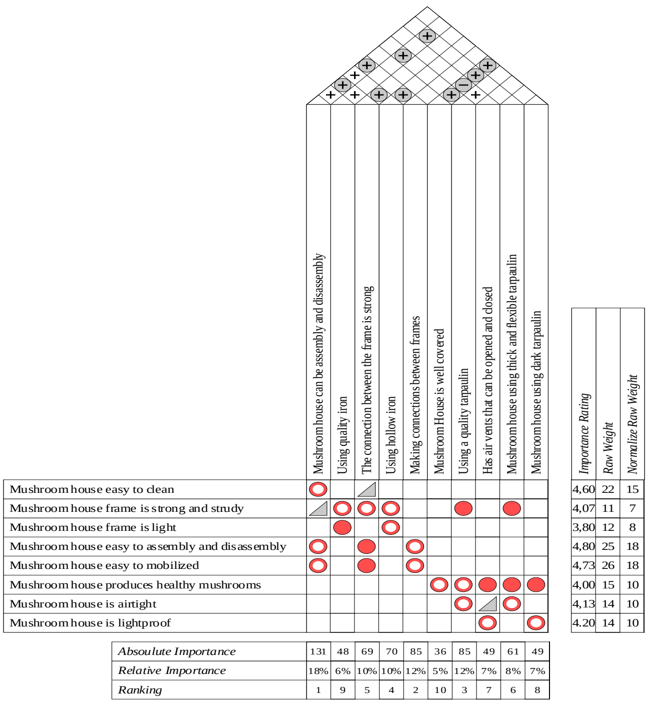

Figure 3. House of quality (HOQ)

2.3. CRITIC Data Collection

There are several specifications of galvanized hollow iron, namely size, thickness, and length, where these specifications will affect the physical properties of the iron, such as the strength of the iron and the ease with which the iron is fabricated. In making decisions that involve criteria, galvanized hollow iron is collected, which has the criteria of weight, thickness, and ease of fabrication. Blankets made of tarpaulin have several basic specifications, namely weight, flexibility, thickness, and durability. The galvanized hollow iron specifications can be seen in Table 3. The tarpaulin specifications can be seen in Table 4.

Table 3. Hollow Iron Material Alternative

Iron Type	Weight	Width	Thickness	Fabrication
Hollow Galvanis 25x25 0,9	4,11	25	0,9	1
Hollow Galvanis 25x25 1,6	7,08	25	1,6	4
Hollow Galvanis 25x25x 2	8,84	25	2	1
Hollow Galvanis 30x30 0,9 mm	4,89	30	0,9	2
Hollow Galvanis 30x30 1,6 mm	8,61	30	1,6	5
Hollow Galvanis 30x30 2 mm	10,96	30	2	1
Hollow Galvanis 20x20 0,9 mm	3,2	20	0,9	1
Hollow Galvanis 20x20 1,6 mm	5,54	20	1,6	4
Hollow Galvanis 20x20 2 mm	6,92	20	2	1

Table 4. Terpaulin Alternative

Tarpaulin Type	Weight	Flexibility	Thickness	Resistance
A3	118	1	1	1
A5	146	1	2	2
A8	195	1	3	3
A12	225	1	4	4
PVC	230	5	5	5

2.4. CRITIC Data Processing

Based on the calculation of the multi-criteria value, the selected material is 30x30 1.6 mm galvanized hollow iron, which has the largest multi-criteria value of 11,182. Thick hollow iron has better strength. However, the thicker the iron, the heavier the iron will be. Heavy iron will affect the ease of disassembling the mushroom house. In addition, if you choose iron with a smaller thickness, it will reduce the strength of the iron. Based on this, it is necessary to use a material selection method that has specific multi-criteria. The selected mushroom house blanket uses a PVC tarpaulin with a multi-criteria value of 69.7. PVC tarpaulin has the highest level of flexibility and thickness, so it is very suitable for maintaining temperature, humidity, and light and supporting loading and unloading activities. The weight of the PVC tarpaulin will be able to be supported by a frame that has a specification of 30x30 1.6 mm. The distribution of the weight of the tarpaulin will be evenly distributed on the frame. The multi-criteria value rank of hollow iron can be seen in Table 5. The multi-criteria value rank of tarpaulin can be seen in Table 6.

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Table 5. Hollow Iron Frame Multi Criteria Value

Iron Type	Multi criteria value	*Rank*
Hollow Galvanis 25x25 0,9	7,767	6
Hollow Galvanis 25x25 1,6	9,337	4
Hollow Galvanis 25x25x 2	9,271	5
Hollow Galvanis 30x30 0,9 mm	9,423	3
Hollow Galvanis 30x30 1,6 mm	11,182	1
Hollow Galvanis 30x30 2 mm	11,055	2
Hollow Galvanis 20x20 0,9 mm	6,285	9
Hollow Galvanis 20x20 1,6 mm	7,698	7
Hollow Galvanis 20x20 2 mm	7,537	8

Table 6. Tarpaulin Multi Criteria Value

Tarpaulin Type	Multi Criteria Value	Rank
A3	34.8	1
A5	43.1	2
A8	57.5	3
A12	66.3	4
PVC	69.7	5

3. Design and Production

3.1. Mushroom House Technical Design

A technical drawing of the mushroom house was made based on the specifications obtained from the QFD and CRITIC calculations. The technical design is made using Autodesk software. The technical design is used as a guide to carry out the mushroom house production process. To facilitate the disassembly process, a series of iron bars are built that can be tightened and stretched. Flexibility is obtained by providing a connection between the piles that can move according to the movement between the frame posts. Figure 4 is a series of stretched left-and right-frames. Figure 5 shows a series of truss parts left and right that are closed together.

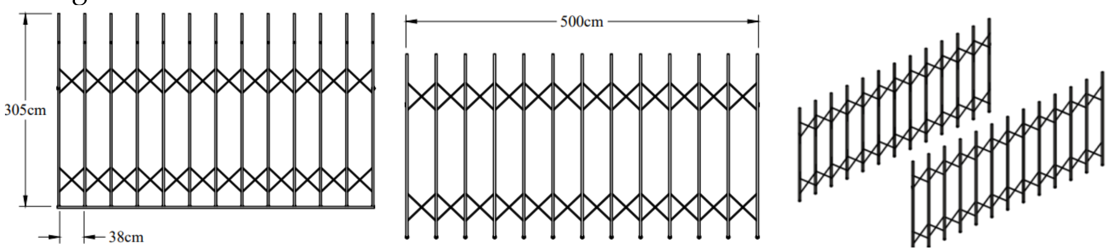

Figure 4. The Left and Right Wall Frames Are Stretched

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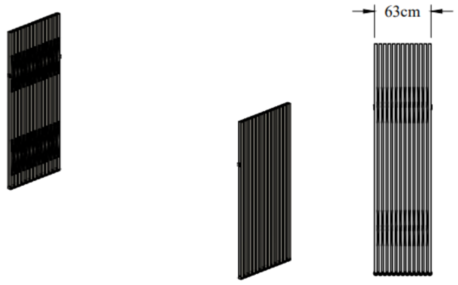

Figure 5. The Left and Right Wall Frames Are Closed Together

In order to be easily stretched and tightened, at the bottom of the frame pillars are given wheels that can be pulled on the foundation floor that has been given a path. Figure 6 is a picture of the connecting post between the left and right flexible frames. The connecting pole serves to bind the left and right frames. In the horizontal connecting post, the two frames are joined together by means of slot ties on the left and right sides of the frame. The vertical connecting pole serves to tie the horizontal pole to the floor foundation. A curved roof frame is formed to be able to withstand rainwater. By making a curved design, water will flow on the left and right of the roof. The roof design can be seen in Figure 7.

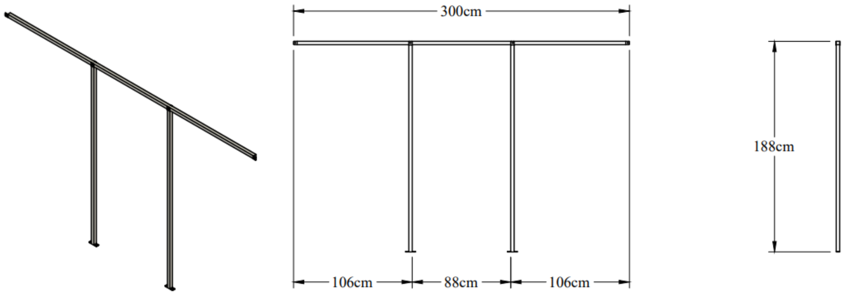

Figure 6. Left and Right Frame Link

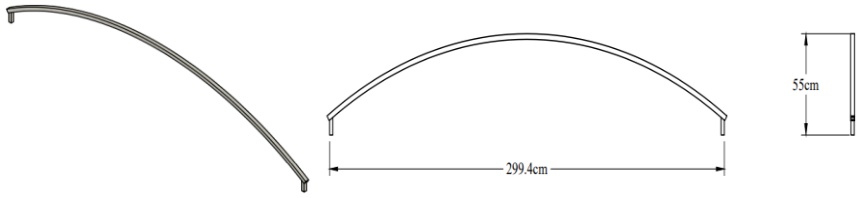

Figure 7. Roof Disassembly and Install

There are four main elements of the assembled mushroom house, including left and right flexible walls; connecting frames; roofs; and foundations. The foundation frame serves as the holder of the frame. Aside from being a support, the foundation also functions as a path used to tighten and stretch flexible walls. The foundation helps the assembly process on uneven and soft ground. By providing a foundation frame, the mushroom house frame can stand upright on the land. The results of assembling the frame before and after being assembled can be seen in Figure 8.

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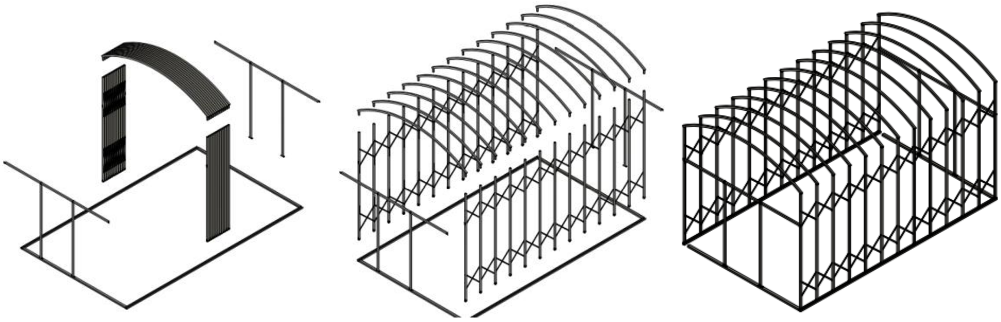

Figure 8. Foundation Frame and Mushroom House Frame Assembly

The design and size of the mushroom blanket are adjusted to the size of the front, back, left, right, and roof walls. For easy installation, the left and right ends are provided with holes that can be used to help install and dismantle the blanket on the frame. In addition to assisting assembly activities, holes are used for fastening pegs so that the blanket is tightly tied to the frame and foundation. The blanket is given a connection in the form of a zipper at each corner of the frame. The provision of zippers aims to assist the disassembled activities. The blanket design can be seen in Figure 9.

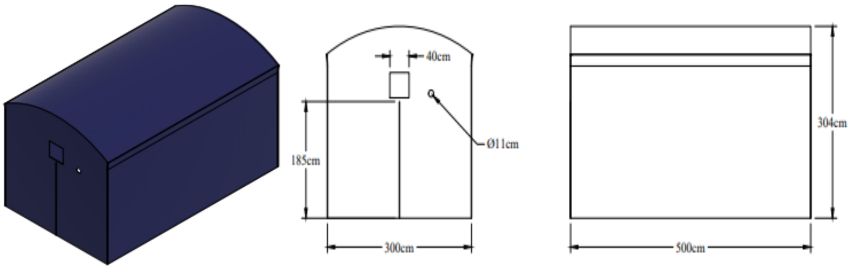

Figure 9. Mushroom House Tarpaulin Design

3.2. Mushroom House Production

The production of the frame and roof begins with the cutting of the hollow iron based on a predetermined size. After being cut, the frame is assembled using flexible joints and tested. The process of testing the flexible wall truss can be seen in Figure 10. Flexible frame testing is carried out to ensure the frame can move freely as designed.

Figure 10. Production and Flexible Frame Testing

Mushroom house blankets are produced by cutting and joining pieces of PVC tarpaulin together. The process of uniting the pieces is done by sewing and hot glue. The hot glue process is carried out by flowing hot air on the surface of the tarpaulin, and then gluing the two surfaces together by applying pressure through iron rollers. The zipper and holes are

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made by sewing using nylon thread. The blanket production process can be seen in Figure 11.

Figure 11. Mushroom House Blanket Production

The assembly process is carried out to ensure that the shells and blankets can function properly. Assembly is carried out by preparing the foundation. The assembly of the foundation is carried out using bolted joints. After the foundation is installed, the left and right flexible walls are connected using the front frame connectors. The roof trusses are installed one by one in order, and after completion, the rear truss connector is installed. Re-check the bolt and slot connections to ensure the connection is firmly fused. The PVC tarpaulin blanket is installed after the frame is firmly established. The installation process begins by stretching the blanket and then pulling it up to the roof until the entire frame is covered. The process of fastening the zipper at each corner of the frame is carried out to ensure the blanket is properly attached. The results of assembling the mushroom house framework can be seen in Figure 12. The blanket assembly can be seen in Figure 13. The results of the mushroom house assembly can be seen in Figure 14.

Figure 12. Frame Assembly

Figure 13. Assembling The Frame and Tarpaulin Blanket

Figure 14. New Design Mushroom House

4. Testing and Analysis

The mushroom house testing was carried out by taking data in the form of assembling and disassembling time, temperature, humidity,and productivity. The measurement results of the mushroom house data were then compared with the traditional mushroom house data. 5 Trials were carried out by combining the amount of labor with the time required to assemble and disassemble the mushroom house. The average mushroom house assembly time is about can be seen in Table 7. The average mushroom house disassembly time can be seen in Table 8.

Table 7. Average Mushroom House Assembling Time

Total Manpower	Assembly Time (minutes)
2	90
3	60
4	45
5	38
6	35

Table 8. Average Mushroom House Disassembly Time

Total Manpower	Disassembly Time (minutes)
2	105
3	80
4	65
5	52
6	40

Based on the disassembly and assembly time data, the longest assembly time was 90 minutes and was carried out by 2 people. The fastest assembly time takes 35 minutes and is carried out by 6 people. The longest disassembly time took 105 minutes and was carried out by 2 people. The fastest disassembly time took 40 minutes and was carried out by 6 people. The process of building a traditional mushroom house can take 3–4 days and requires a total workforce of 3 people. When compared to traditional mushroom houses, the designed mushroom houses are superior in terms of time and ease of assembly and disassembly. The mushroom house frames and blankets can be loaded into pick-up trucks and then transferred from one oil palm plantation to another.

Humidity and temperature measurements were carried out in the morning, afternoon, evening, and night. Data was taken for 30 days using an Arduino microcontroller to record the temperature and humidity values. The data is then processed to determine the average value and range of temperature and humidity. The measurement results show that the designed mushroom house can maintain humidity in the range of 70–80% and a temperature in the range of 30–35 °C in accordance with the standards required for the growth of straw mushrooms. The data showed that the average temperatures and humidity were 28,07 ± 2,25 °C and 93,89 ± 7,06% [10]. An important environmental requirement during the cropping of mushrooms is that the evaporating power of the air circulating over the beds should lie within specified limits [9].

Based on 5 planting experiments, the growth rate of straw mushrooms in the designed mushroom house was more optimal when compared to the traditional mushroom house. The percentage of wild mushrooms growing on the oil palm empty fruit bunch media decreased by about 10–20%. Oil palm empty fruit bunch media can be grown as much as 85-90%. The increase in the amount of growth was obtained because the post-harvest land sterilization process could be done by dismantling the mushroom house. Land, tarpaulin, and hollow iron frames can be cleaned that are exposed to direct sunlight, making the process of sterilization more optimal.

5. Conclusion

Based on the results of research and measurements that have been carried out, it can be concluded that the mushroom house design is able to meet the needs of farmers in terms of productivity and flexibility. Increased productivity can be realized by the ability of the mushroom house to maintain temperature and humidity and the ease of sterilization of land, frames, and tarpaulins. Flexibility can be realized by the ease of assembly, disassembly, and mobilization processes.

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