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Design of tofu pressing tool based quality function deployment: A case study

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Abstract

This paper aims to design an innovative tofu pressing tool using the Quality Function Deployment (QFD) to increase the productivity of tofu in Small and Medium-sized Enterprises (SMEs). A case study was carried out at the Wardi Tahu enterprise in Indonesia. The QFD method was adopted in this study to integrate the customer's needs into the design process for the tofu press device. The House of Quality (HoQ) was developed to determine the relationship between technical characteristics and the customer's needs to obtain the design decision for the tofu pressing device. The determination design of the tofu press tool resulted in an innovative pneumatic system: tofu mould covers with perforated plates, removable tofu mould covers, corrosion-resistant materials, electric actuators, simple switching system, hygienic, modular design, formability and machinability, and easily accessible components. As a result, in this study, a pneumatic system tofu pressing machine has advantages over a manual tool, such as no longer need to lift a bucket filled with water as ballast, being easy to operate, being safe when operating, and simple, the tool can press faster, corrosion resistant and hygienic material of tool, easy to clean tool, increase the amount of production and hygiene process of tofu production.
Keywords: Customer voice, innovative design, quality function deployment, tofu pressing tool.

1. Introduction

The high demand for tofu makes the development of the tofu-making industry more rapid. This can be seen from a large number of tofu-making industries, both at home scale with a small number of workers and large-scale industries with a larger number of workers, where the tofu production process generally still uses traditional tools (Soares et al., 2019). The tofu production process begins with the selection of soybean raw materials, soaking, grinding, cooking, filtering, clumping, pressing, printing, and cutting. One of the processes of pressing tofu that is still carried out by many SMEs (Small and medium-sized enterprises) is the traditional process of using river rock or a bucket filled with water, which this traditional process of pressing tofu takes a long time. Other tools use levers and human power as actuators during the pressing process, so they are less effective in terms of time and effort. Therefore, an innovative design of a tofu press tool is needed to suit the needs of SMEs, which are expected to be able to help SMEs increase the productivity of tofu production. One design method that accommodates customer needs is Quality Function Deployment (QFD) method.

The Quality Function Deployment (QFD) is a tool that helps translate consumer language into a product that truly meets consumer needs (Jaiswal, 2012). The QFD is a methodology for translating consumer wants and needs into a product design that has certain technical requirements and quality characteristics (Aydin et al., 2023; Rahman et al., 2023; Yang et al., 2022). The basic target of QFD is to motivate product developers through a systematic method of transmitting the voice of the customer to designs so that an evaluation of potential responses to meet universal consumer wants and needs is obtained. This is important because almost all organizations (businesses) experience competition, such as price changes, new product introductions, or product innovations on existing products. Some of the advantages of implementing QFD are: improving product quality, increasing customer satisfaction, improving communication, increasing productivity, increasing product excellence, shortening time to market, reducing design budgets, and increasing company profits (Asfia et al., 2021; Wolniak, 2018; Zengin & Ada, 2010).

There are several important aspects of the QFD system (Govers, 2001), such as the main focus of QFD are customer needs and consumer expectations for the product. Usually, QFD is based on projects and the use of cross-functional teams, which states that all members involved in the product development organization influence the product. One of the QFD tools is the House of Quality (HoQ), which is a graphical technique for defining the relationship between customer desires and products or services (Nugroho & Susilowati, 2022; Aghdam et al., 2015; Kuei, 2002). The HoQ is compiled from the level of interest by consumers, the level of customer satisfaction, technical parameters, the relationship between consumer interest attributes and technical parameters, analysis of the relationship between technical parameters, the value of the level of technical importance, and the value of the level of relative technical importance, which can be seen in one scheme (Prasad, 1998; Wicaksono et al., 2021).

The use of the QFD method with a house of the quality tool has been carried out by several previous researchers to link customer desires with product design (Sivasankaran 2021; Arifin et al., 2021; Bigorra & Isaksson, 2017; Mesbahi et al., 2020; Pardosi & Susilawati, 2023; Yohanes & Azhar, 2023; Sidanta, et al., 2016). Research results on Pardosi & Susilawati (2023) designed an areca nut peeling machine based on the Quality Function Deployment (QFD) and HoQ method to optimize the areca nut peeling process. Yohanes & Azhar (2023) used the Quality Function Deployment (QFD) method to design biomass stove products and the House of Quality matrix was used to analyze people's wishes associated with the design features of biomass stove products. The research conducted by Sidanta et al. (2016) designed a tofu pressing machine using Quality Function Deployment (QFD) and Teorija Rezhenija Izobretatelskih Zadach (TRIZ) method. However, it was a manually press machine, which manually processes that takes quite a long time to produce the tofu. Considering operating time is very important, with good time management, can increase the amount of production. Maukar et al. (2019) developed a tofu device in the form of a multi-level wooden box. In the wooden box is carried out the process of pressing tofu, filtering tofu wastewater, printing, and cutting tofu. This device can replace the process of compacting, pressing, filtering, printing, and cutting tofu in one system. However, it uses manpower to operate the device. Using human power as a compressive force is less efficient because the force exerted is not constant. Each human being does not exert the same force on the pressure lever. Therefore, the purpose of this study is to design an innovative pneumatic system for tofu pressing tools using the Quality Function Deployment (QFD) method to help increase tofu productivity in SMEs (Small and Medium Enterprises. A case study was conducted in a tofu factory on an SME scale in Pekanbaru City, Indonesia.

2. Method

This study adopted the QFD method using the HoQ tool approach. The research was conducted at the Wardi Tahu factory, a Small and Medium Enterprise scale factory in Pekanbaru City, Indonesia. The tofu production process in the case study used traditional tools, especially for pressing, still using a 25 kg water bucket as the ballast. The bucket was filled with water until it was complete. The pressing process that used this bucket still has drawbacks and a low level of security. Tofu mold containers still used wood, which was the wood material that quickly weathered caused by the water used. Therefore, this research designed an innovative tofu press tool that can make it easier for the tofu industry players to ease the work in the tofu pressing process according to customer wishes (the case study was conducted in the Wardi Tahu factory). The use of Quality Function Deployment (QFD) in this design process was to determine the needs of the tofu pressing tool required by the Wardi Tahu factory.

The census sampling method was used in this study. The census was a sampling technique when all members of the population were used as samples (MacDonald, 2020; Skinner, 2018). The samples in this study were all employees of the Wardi Tahu factory with 8 respondents, 5 men and 3 women. This sampling was carried out for all employees in the case study according to the census sample method. Direct interviews with tofu-making workers carried out the identification of consumer needs. This interview was conducted to obtain the needs of tofu-making workers for tofu press tools. In the interview, statements were obtained from tofu pressing workers. It can be seen in Table 1.

The results of the interpretation of consumer needs were used in determining product attributes. A closed questionnaire was made from the results of interviews that produced interpretations of needs and product attributes.

Table 1. Identification of consumer needs in a case study.

No.	Statement	Interpretation of needs
1	The slip when lifting a bucket filled with water as a ballast resulted in an injury to the operator	Safe tools to used
2	Lifting a bucket filled with water causes pain in the body	Convenient tool to use
3	The ballast takes a long time to finish pressing	More efficient ballast
4	Weathered mold cover	Requires a material that resistant to water
5	Clean the old mold cover	Easy-to-clean mold cover material
6	Small-size mold requires a lot of tofu mold	Additional dimensions according to production needs

The closed questionnaire research related to consumer needs consists of 6 questions, which were answered by respondents using a Likert scale (Mushtaha et al., 2022; Akdağ et al., 2016). This study adopted a 5-point Likert scale: (1) Not important, (2) Less important, (3) Important, (4) Very important, (5) Extremely important. The six consumer needs were used as the basis for the questions in the research questionnaire:

1. Tool was easy to operate.
2. Tool was safe when operated and simple.
3. Tool can press faster.
4. Corrosion-resistant and hygienic material.
5. Easy to clean tool.
6. Increase the amount of production.

The questionnaires were distributed to Wardi Tahu staff and management, where all employees served as resource persons to fill out the questionnaire. After obtaining the voice of the customer from the closed questionnaire, a house of quality was built. The stages of building a house of quality:

1. Determine the technical characteristics.

Technical characteristics were: the way and how the voice of the customer was executed. In other words, the characteristic of the technique can be achieved by the engineer to fulfil the consumer's desire.

2. Determine the relationship between technical characteristics.

The relationship between the technical characteristics was obtained through the distribution of the questionnaire to experts. At this stage, the relationship between each of the existing design characteristics was determined to analyse whether there was a contradictory (negative) relationship between these technical characteristics. The level of relationship between technical characteristics and the customer's needs was described as the level of relationship between each of the existing technical characteristics. The following symbols were used (Cohen, 1995):

+ = level of strong positive relationship (value 4).
+ = moderate positive relationship level (value 3).
O = no relationship (value 2).
- = medium negative relationship level (value 1).
- = level of strong negative relationship (value 0).

The relationship between the technique characteristics produced a degree of difficulty, which was a value in the difficulty level of a technical characteristic (Table 2).

Table 2. Level of difficulty (Cohen, 1995).

Level of difficulty	Statement
1 – 5	Easy
6 – 10	Quite easy
11 – 15	Difficult
16 – 20	Very difficult

Determining the relationship between technical characteristics and the voice of the customer was the distribution of questionnaires to produce a degree of importance. It became the importance level value of the technical attributes. The questionnaire started from a scale of strong, medium, weak, and not related at all. The assessment was based on the rules (Cohen, 1995):

Value 5: indicates a strong relationship.
Value 3: indicates a moderate relationship.
Value 1: indicates a weak relationship.
Value 0: indicates no relationship at all.

The relationship between technical characteristics and the voice of the customer produced a degree of importance. The degree of importance was a value of the level of importance of technical attributes (Table 3). Determining the relationship between technical characteristics and the voice of the customer was the distribution of questionnaires to produce a degree of importance. It became the importance level value of the technical attributes. The questionnaire started from a scale of strong, medium, weak, and not related at all. The assessment was based on the rules (Cohen, 1995):

Value 5: indicates a strong relationship.
Value 3: indicates a moderate relationship.
Value 1: indicates a weak relationship.
Value 0: indicates no relationship at all.

The relationship between technical characteristics and the voice of the customer produced a degree of importance. The degree of importance was a value of the level of importance of technical attributes (Table 3).

Table 3. Level of importance (Cohen, 1995).

Level of importance	Statement
1 – 5	Not too important
6 – 10	Quite important
11 – 15	Important
16 – 20	Very important

Finally, the House of Quality (HoQ) was constructed based on the sequence's priorities, design targets, and demand fulfilment embodied in the technical specifications of the latest design development.

3. Result and Discussion

Table 4 displays the outcomes of the research questionnaire data collection. The amount of relevance for each consumer demand was computed using the Likert technique, which involved adding up all of the respondents' preferred values for each item. The level of relevance was calculated based on the total values.

The customer's voice was determined via distributing questionnaires. Table 5 shows a recapitulation of open questionnaire findings from highest to lowest ratings. Technical characteristics were arranged based on consumer needs resulting from a closed questionnaire.

The determination of technical attributes was four criteria: materials, control systems, design concepts, and drive resources. Based on the four criteria, the feature of the technique obtained 9 points of technical attributes as follows:

1. Corrosion resistant material
2. Hygienic
3. Formability and machinability
4. Modular design
5. Components are easy to find
6. Mould cover using a perforated plate
7. Simple switching system
8. The mould cover was effortlessly off
9. Electric actuator

The expert gave a scoring to determine the relationship among the technical characteristics, between the customer's requirement and each technical attribute. Fig. . ure 1 shows the results of assessing the relationship between technical characteristics.

The final HOQ results show the priority of technical characteristics. The priority order of technical attributes from highest to lowest values; can be seen in Fig. . ure 2. The value of the most importance level to less importance level of technical characteristics priority was:

1. Cover of tofu mould using a perforated plate
2. The lid of the tofu mould was easy to remove
3. The material was resistant to corrosion
4. Electric actuator
5. Simple switching system
6. Hygienic
7. Modular design
8. Formability and machinability
9. Components were easy to find.

Table 4. Questionnaire summary result in the case study.

Respondent	Result of Questionnaire					
	The tool was easy to operate	The device was safe when operational and simple	The tool can press faster	Tool material was corrosion-resistant and hygienic	The device was easy to clean	Increasing the amount of production
Respondent 1	5	5	5	4	4	5
Respondent 2	5	5	4	4	4	5
Respondent 3	5	5	5	5	5	5
Respondent 4	5	5	4	4	3	5
Respondent 5	5	5	5	5	5	5
Respondent 6	4	4	3	3	3	4
Respondent 7	5	5	5	5	4	5
Respondent 8	5	5	5	4	5	5
Total	39	39	36	34	33	39

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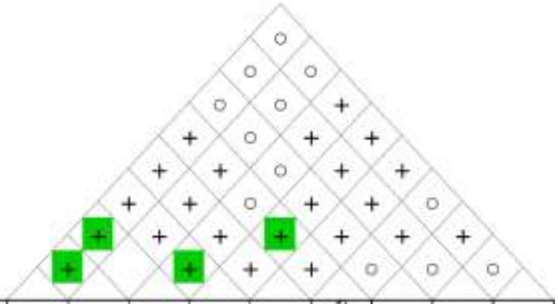

Customer Requirements \ Functional Requirements		Corrosion resistant material	Hygenic	Formability and machinability	Modular design	Components are easy to find	Mold cover using a perforated plate	Simple switching system	Mold cover is easy off	Electric actuator
Tools that are easy to operate	39							5	5	5
Tool that is safe when operated and simple	39							3	3	3
Tools can press faster	36			1	1		5	1		5
Corrosion resistant and hygienic material	34	5	5	3	5	5	5			
Easy to clean tools	33	5	5	3	3		3		5	
Increase the amount of production	39	3		1		1	1			
Relative Weight		452	335	276	304	209	488	348	477	420

Fig. 1. House of Quality (HoQ) in the case study.

The technical characteristics used as the basis for the innovative design of the tofu press tool. The electric actuator functions as a source of propulsion for the device. The operation of the tofu press tool is designed to use a pneumatic system. Based on the HoQ and priority of technical characteristics, the design of the tofu press tool is shown in Fig. . ure 3.

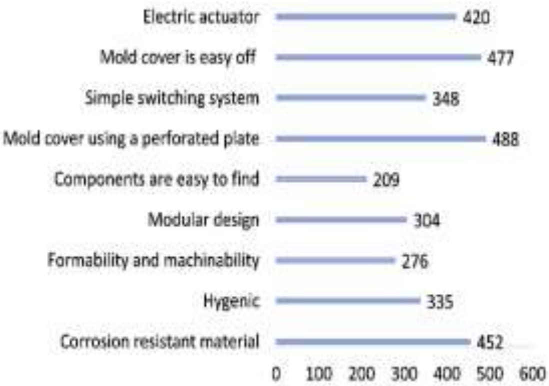

Fig. 2. The value of priority technical characteristics.

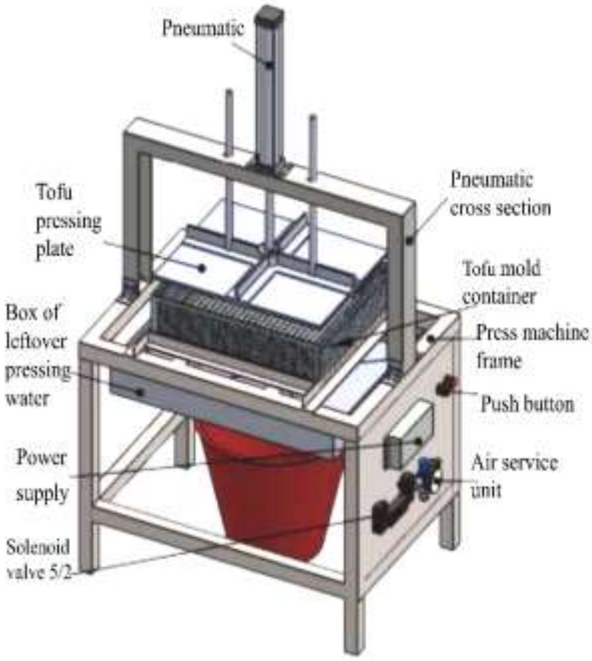

Fig. 3. Design of a pneumatic system of tofu pressing tool.

The stainless steel was the material for the pneumatic system of the tofu pressing tool. Stainless steel has various advantages as being rust-resistant and easily cleaned. The application of this material answered the consumer's needs for materials that were resistant to corrosion and hygienic, as well as for tools that were easy to clean. The pneumatic type was SC 32x500 of pneumatic standard cylinder, double acting type cylinder. A double-acting pneumatic cylinder has two ports that allow pressure to pull the piston in the opposite direction to that created by the first port, otherwise known as fast travel and outward stroke. The pneumatic press referred to the consumer's need for a tool that was safe when operating and simple.

The height of the tofu press tool structure was 700 mm, 650 mm wide, and 1000 mm long (Fig. . ure 4). The machine structure height of 700 mm can make it easier for the operator to fill the tofu essence during the pressing process. The structure width of 1000 mm can increase the size of the tofu container compared to the old tool was too small. The iron plate that was on the top side of the frame served to hold the tofu container. Hence, it remained a flashlight with the tofu pressing plate.

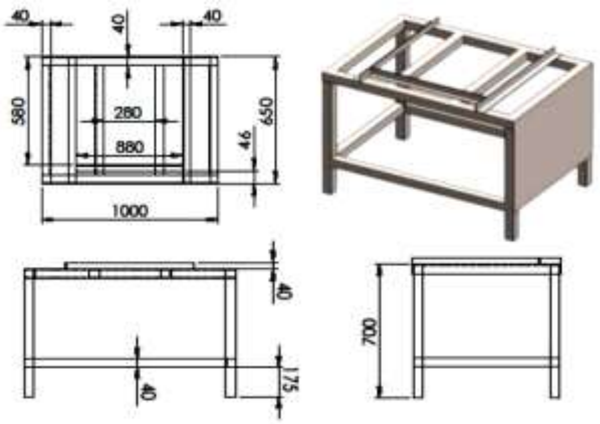

Fig. 4. Design of tofu press machine structure.

Previously, the tofu mould container size was 500 mm x 500 mm. According to customers' needs in the case study, this increased the production output. Therefore, the new design of the tofu mould container size was modified to 580 mm x 880 mm (Fig. . ure 5a). Increasing tofu container size can raise the amount of tofu production. The container for the tofu mould is divided into two parts. The first part was the cover for the tofu mould with a height of 150 mm and the base for the mould with a high of 50 mm. The purpose of dividing this into two parts was to make it easier for the operator when cutting tofu. It was suitable according to consumer needs and awarded the first preference (Table 5), which was an easy-to-operate press tool. The material used in the tofu mould container of a perforated stainless steel plate with a thickness of 5 mm. The hole in the tofu mould container was to speed up the separation of water and tofu starch during the pressing process.

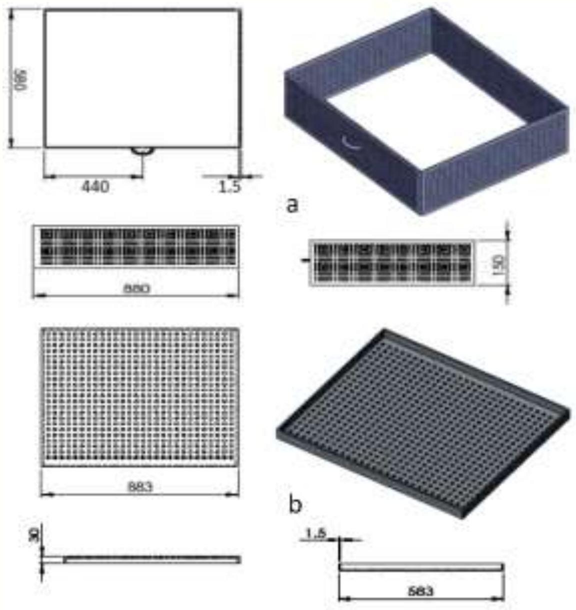

Fig. 5. Design of (a) tofu mould container cover, (b) tofu mould container base.

The box functions as a reservoir for water from tofu starch, which was squeezed out during the pressing process. So, it did not get scattering and can be directed to the bucket. The box size was 920 mm x 600 mm. The box of water left over from pressing functions as a reservoir for water from tofu starch. The size of the remaining pressed water box was determined proportionally to the size of the press machine frames. The design of the remaining pressed water box can be seen in Fig. . ure 6.

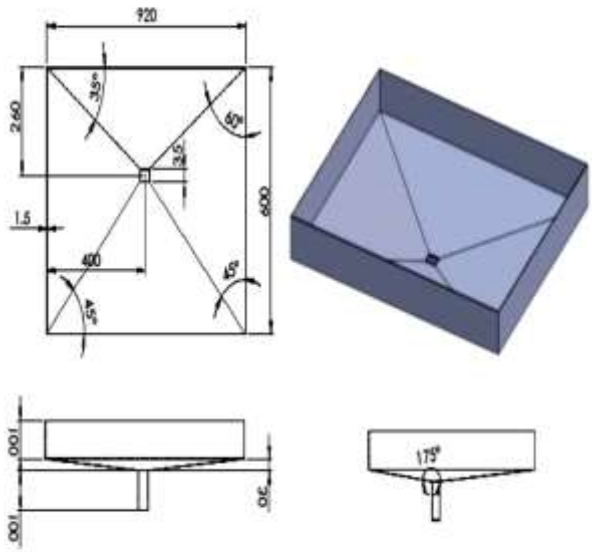

Fig. 6. The box of reservoir for water tofu starch.

The tofu pressing plate functions to transform the pneumatic thrust to all sides of the tofu container during the tofu pressing process. The design of the plate for press tool tofu can be seen in Fig. . ure 7. The size of the tofu pressing plate was 877 mm x 577 mm.

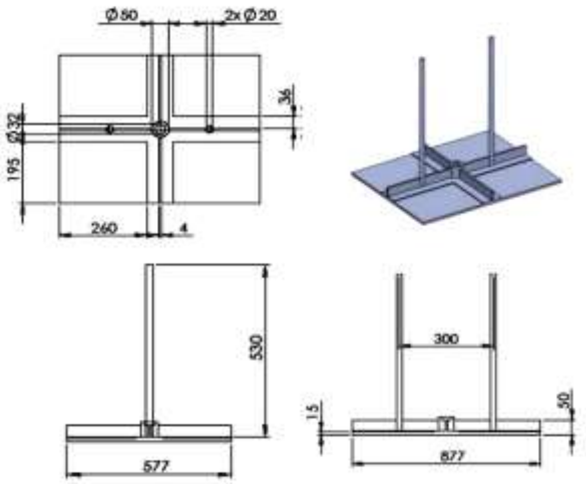

Fig. 7. The plate of the tofu press tool.

The pneumatic support pole served to support the pneumatics. The size of the pneumatic support pole was 1000 mm long, 50 mm wide, and 700 mm high. The design of a pneumatic support pole for press tool tofu can be seen in Fig. . ure 8. The size of the pneumatic support rod with a length of 1000 mm was proportional to the length of the machine table. The width of 50 mm was obtained from the dimensions of the U-channel iron used, and the height of 548 mm was obtained from the piston rod length of 500 mm plus the final result of pressing, which was 25 mm (thickness of tofu) and the size of the pressing plate that has been installed with a pneumatic cylinder, which was 23 mm. The pneumatic support pillar served to support the pneumatic cylinder. The pneumatic support pole design can be seen in Fig. . ure 8.

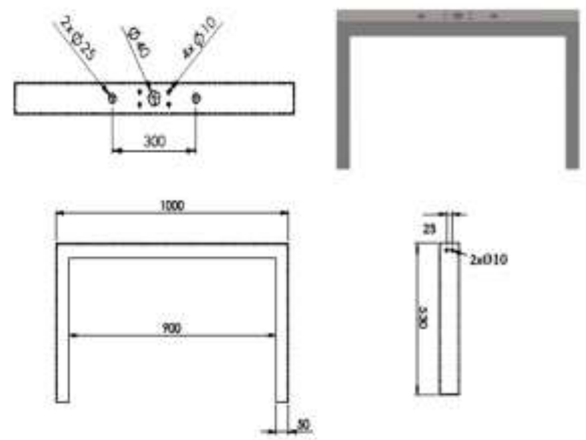

Fig. 8. The pneumatic support pole of the tofu press tool.

To assess the final result of a product as a good design value category consists of three elements must be met, functional, aesthetic, and economic (Zengin & Ada, 2010; Han et al., 2021; Candi et al., 2017). The function and aesthetic elements are often called fit-form-function, while the economic element is more influenced by price and purchasing power. Therefore, the functional element has been fulfilled with benefits for tofu entrepreneurs who still use the traditional pressing method. This study resulted in a pneumatic system tofu pressing machine design that can benefit tofu entrepreneurs such as: no longer need to lift a bucket filled with water as the ballast, easy to operate the tool, the tool is safe when operated and simple, tools can press faster, corrosion resistant and hygienic material of tool, easy to clean tool, increase the amount of production, and hygiene process of tofu production. This tofu press device design can combine several processes to save time in the production process of tofu as compacting and pressing tofu, and filtering out excess water. In addition, workers do not directly touch the tofu in the pressing process and filter out the leftover tofu. Sub-sequence, it can improve hygiene in tofu products.

The aesthetic element has been fulfilled with the appearance of a pneumatic system tofu pressing machine that looks modern. Whilst, the economic factor can be assessed after calculating the cost, which can be conducted in future studies.

4. Conclusion

The purpose of this study was to design an innovative pneumatic tofu pressing machine using the Quality Function Deployment (QFD) method as a case study. Based on the result in the case study obtained voice of the customer, namely: the tool was easy to operate, safe, and simple; the tool could press faster; the materials were corrosion resistant and hygienic; easy to clean, and increased the amount of production. Then, the technical characteristics, which were parameters of importance level of an innovative pneumatic system tofu pressing machine design, namely: the cover of the tofu mould using a perforated plate, the cover of the tofu mould can be removed, the material was resistant to corrosion, electric actuators, simple switching systems, hygienic, modular design, formability, and machinability, and easy to find components.

The priority of technical characteristics based on the level of importance was the tofu mould cover using a perforated plate value of 488, the tofu mould cover can be removed value of 477, the material that was resistant to corrosion value of 452, the electric actuator value of 420, the simple switching system value of 348 and the hygienic value of 335. This level of importance shows the most important thing in the design process of a pneumatic system tofu pressing machine. Further research can be carried out on design development, both in terms of the shape and size of a pneumatic system tofu pressing machine as well as the production cost analysis, manufacture, and test of the pneumatic system for the tofu pressing machine.

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