Application of House of Quality in the Design Requirements for Flakes Machines in the Banana Flakes Production Process

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Keywords: Banana Flakes, Design Requirement, Flakes Machine, House of Quality, Quality Function Deployment.

Abstract: Banana flakes are products with the main ingredients that contain ripe banana flour. The use of ripe banana flour will make the dough sticky and mushy, which is a problem in the banana flakes production process. These problems are such as the difficulty in the process of forming dough sheets, the process of cutting flakes, and the sticky dough on the tool. Therefore, to solve these problems need planning and problem solving based on customer requirements to design flakes machine. To identify design requirements based on these problems using one of the planning phases of quality function deployment (QFD), called the house of quality (HOQ). HOQ is a planning and problem-solving tool for the design team that functions to provide input into the design process phase. The application of HOQ focused the design team's attention on customer satisfaction during the product design and development process. HOQ gives relationship matrix between customer requirements (CRs) and engineering characteristics (ECs) that will produce recommendations and constraints that must be considered when designing a product. Based on the application of HOQ revealed that there are three highest ranks of a total of 17 ECs, namely the production time of 13.44%, the automation of machine of 11.46%, and the production capacity of 10.05%, its means that the design focus for flakes machine must lead based on the analysis.

1 INTRODUCTION

Banana is a horticultural commodity that grows in Indonesia. Indonesia has almost 200 types of bananas (Fatmawati and Dianawati, 2016). Bananas contain carbohydrates 22.84 g/100 g, vitamin C 8.7 mg/100 g, and minerals (potassium 358 mg, magnesium 27 mg, phosphorus 22 mg, calcium 5 mg, sodium 1 mg, and iron 0.26 mg per 100 g) (Mahmudah, Amanto and Widowati, 2017). Other than that, bananas contain prebiotics and have benefits for the human (Desnilasari and Lestari, 2014). One of diversification of the production process of bananas is banana flour (Surahman *et al.*, 2019). One of the products of banana flour processing is banana flakes. Banana flakes are flakes food products from ripe banana flour which is an alternative for breakfast (Setyadi, 2016; Surahman *et al.*, 2019).

However, the production process of banana flakes made from ripe bananas has constraints in increasing production capacity caused by dough sticky and mushy. Some banana flakes production processes still use simple and manual equipment. To design the machine flakes in the banana flakes production process needs some initial analysis in solving problems based on customer requirements (CRs) with the identification method of the design requirements using one of the planning phases of the QFD, called the HOQ (Dieter and Schmidt, 2013). Regarding the methods for designing the new product development, Quality Function Deployment (QFD) is a significant methodological approach to enhance customer satisfaction and reduce the production costs (Zadry *et al.*, 2015). QFD has been profitably applied by industries around the world (Dieter and Schmidt, 2013; Zadry *et al.*, 2015). The objective of this paper with HOQ methods is to give relationship matrix between CRs and engineering characteristics (ECs) that will produce recommendations and constraints which must be considered when designing the product.

2 MATERIALS AND METHODS

In application HOQ, there are two sides to the analysis. The first is collecting data to identify customer preferences for banana flakes product

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characteristics (Zadry *et al.*, 2015; Djekic *et al.*, 2017). The second is comparing CRs that have been obtained from the analysis results of data collection with ECs (Dieter and Schmidt, 2013).

2.1 Preliminary Study

Preliminary study on the QFD concept was conducted observations and interviews directly with customers (Zadry *et al.*, 2015). In this case, customers are the makers of banana flakes or the producer banana flakes. Interviews were conducted to obtain information based on complaints that occurred. The interview is the initial stage which aims as a reference in designing the questionnaire and an initial description of the needs and expectations of customers to design machine flakes in the banana flakes production process.

2.2 Customer Requirements Data Collection

Data collection was carried out using a questionnaire. Questionnaires are distributed to customers to find out what complaints and customer needs regarding the production process that is being used as well as the expected production process. The use of questionnaires is also used to find out ideas related to the design of flakes machines (Zadry *et al.*, 2015). The questionnaire was developed based on interview data and direct observations that refer to the quality dimension (Dale, 2003). Grouping CRs include performance, durability, reliability, features, and aesthetics. Questionnaires based on CRs were given from least important (1) to most important (5).

2.3 Concept of QFD

QFD is a systematic approach that focuses on the initial design of the design team on user satisfaction to make a machine that can work according to CRs (Dieter and Schmidt, 2013; Prasad and Chakraborty, 2013). The complete QFD process is diagrammed in Figure 1, Figure 2, Figure 3, and Figure 4. That figures is the four phases of QFD process (Tsai *et al.*, 2008).

The QFD process consists of four phases that are the steps towards accountable design results. The results of each phase becoming the input to the next (Dieter and Schmidt, 2013). The initial stage of the QFD is that HOQ serves to guide the design team in determining the ECs that have the most influence on CRs. The basic translation of CRs into ECs can be

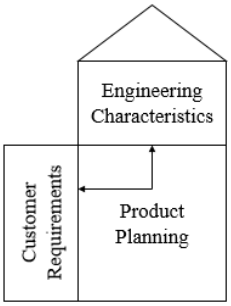


Figure 1: Phase 1. House of quality.

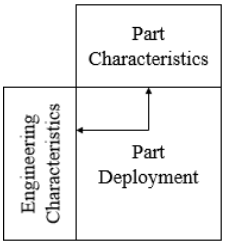


Figure 2: Phase 2. Part of deployment.

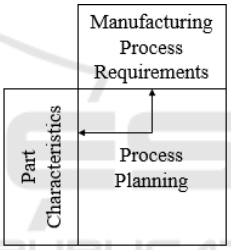


Figure 3: Phase 3. Process planning.

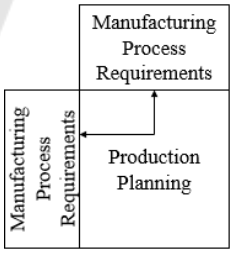


Figure 4: Phase 4. Production planning.

accomplished with a HOQ consisting of Rooms 1, 2, 4, and 5 (Dieter and Schmidt, 2013). Room 3 correlation matrix can be added to find out the correlation on ECs for design consideration.

The HOQ matrix is introduced as follows: Functions in Room 1 represent needs or desires from customers. Based on their desires, the customers may give different importance rating (Chen *et al.*, 2017). ECs in Room 2 are product performance measures and features that have been identified. ECs include production need, engineering analysis, and key part

reliability. ECs are usually measurable values and their units are placed near the top of Room 2. Symbols indicating the preferred improvement direction of each EC are placed at the top of Room 2. Thus a ↑ symbol indicates that a higher value of this EC is better, and a ↓ symbol indicates that a lower value is better. It is also possible that an EC will not have an improvement direction (Dieter and Schmidt, 2013). The Correlation matrix in Room 3 shows the degree of dependence among the engineering characteristics in the roof of the HOQ. It is best to recognize these correlated relationships early so that appropriate trade-offs can be made during embodiment design. The correlation matrix shows that there are strong positive correlations (indicated by "++"), positive (indicated by "+"), negative (indicated by "-"), and strong negative (indicated by "--") among EC pairs.

In the Room 4, the Relationship matrix is at the center of an HOQ. Each cell in the matrix is marked with a symbol that indicates the strength of the causal association between the EC of its column and the CR of its row. The scoring scheme for each cell is given as a set of symbols that represent an exponential range of numbers (9, 3, 1, and 0). The EC will contribute to fulfilling the CR in the cell's row significantly (9), moderately (3), or slightly (1). The cell is left blank if the EC has no impact on the CR (Dieter and Schmidt, 2013). Importance ranking in Room 5 present priorities and goals for product design or improvement. They summarize basic data representing CRs and can help indicate strategic opportunities (Ramírez, Cisternas and Kraslawski, 2017).

The procedures of the traditional HOQ chart of QFD are divided into the following five steps (Figure 5). Step 1: Identifying the CRs, step 2: Determining ECs, step 3: Determining correlation matrix, step 4: Translating CRs into measurable ECs, and step 5: Setting engineering targets for the design.

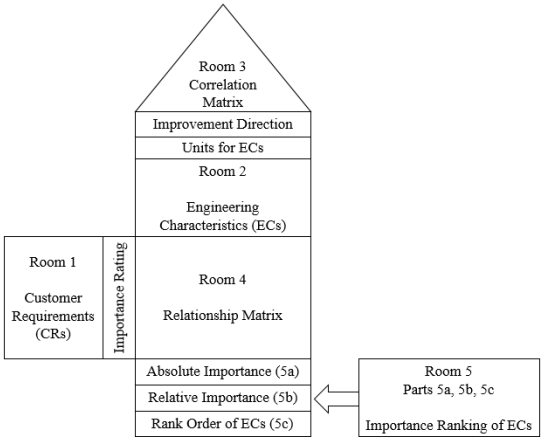


Figure 5: The HOQ matrix (Dieter and Schmidt, 2013).

3 RESULT

3.1 Customer Requirement Analysis

The first stage in the HOQ analysis is to identify customer needs so that it can produce flakes machine design based on needs. CRs based on the results of the questionnaire is importance rating rate, which is the average rating of all respondents or users. Table 1 shows the classification of customer requirements based on observations and interviews conducted.

Table 1: Classification of customer requirements based on observations and interviews conducted.

Criteria	Customer requirements	Importance rating rate
Performance	Scaling up	4.6
	Reduce manual production process	4.4
	Integrated with existing systems	4.4
Durability	Continuously	4
Reliability	Operated for mushy and sticky dough	4.6
	Make the thin sheets dough	4.4
	Easy to use	4.6
Features	Produce uniform products	4
	Replace the manual flakes cutting process	5
	Reducing the stages of the production process	4.4
	Hygiene Products	4.8
	Easy to carry and move	3.6
Conformance	Minimize noise	4
	Energy saving	2.4
Serviceability	Materials availability	1.4

3.2 HOQ

3.2.1 Engineering Characteristics

HOQ is generated by connecting CRs with ECs. ECs are carried out in consultation and discussion by the design team based on CRs. Symbols (↑ and ↓) on ECs indicate improvement direction. ECs for machine

flakes in the banana flakes production process can be grouped into three categories such as Table 2.

Table 2: Engineering characteristics.

Categories	Engineering characteristics	Units	Imp. direction
Production needs	Production capacity	Kg/ batch	↑
	Production time	s	↓
	Automation of machine	n/a	↑
Engineering analysis	Material selection of machine	n/a	-
	Manufacturing process selection	n/a	-
	Safety factor	n/a	↑
	Dimension of machine	m	↓
	Mass of machine	Kg	↓
	Life time	cycle	↑
	Force	N	↓
	Vibration frequency	Hz	↓
	Material strength	MPa	↑
	Energy consumption	n/a	↓
	Assembly	n/a	-
	Maintenance	n/a	↓
Dough properties	Product viscosity	Pa.s	↑
	Product density	Kg/m^3	↓

3.2.2 HOQ Matrix for Flakes Machine in the Banana Flakes Production Process

By applying the QFD method, a HOQ is built as shown in Figure 6.

4 DISCUSSION

For the case of HOQ, the decision-making process is supported by straightforward specification of CRs (Ramírez, Cisternas and Kraslawski, 2017). It results in the identification of suggested changes to the analyzed technology. The application of HOQ in the design of flakes machine in the banana flakes production process resulted in 17 ratings according to the number of ECs. Figure 3, rank order is generated from a percentage from the highest to lowest relative weight. Based on the relationship between CRs and ECs shows that the three highest-ranking according to the customers are production time of 13.44%, automation of machine of 11.46%, and production capacity of 10.05%, its means that the design focus for flakes machine must lead based on the analysis.

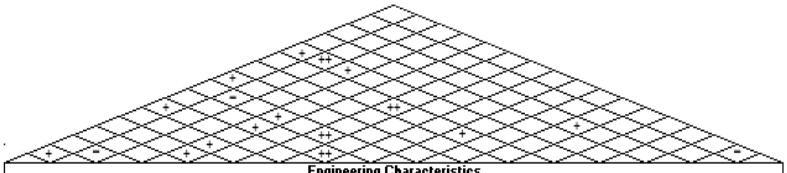
The highest-ranking ECs from the HOQ are either constraints or design variables whose values can be used as decision-making criteria for evaluating candidate designs. There are certain design parameters that can only take a few discrete values. If so, the design team should review the possible values of the EC, determine which is best at meeting correlated EC targets of the design, and then use only the selected value of the EC in generating conceptual designs. The results from the HOQ act as a guide to assist the team in determining the selection criterion for evaluating designs. However, in designing the machine flakes need to consider other ECs to meet customer satisfaction. The lowest-ranking ECs of the HOQ are not as critical to the success of the design. These ECs allow freedom during the design process because their values can be set according to priorities of the designer.

The three highest ranks indicate that users need a machine that can streamline the banana flakes production process and improve the quality and quantity of banana flakes products. The three highest ranks are in the category of production needs in ECs. Caused by the majority of respondents only being customers or operators of flakes machines. This information allows a design team to allocate design resources to the product performance aspects or features (ECs) that are most critical to the success of the product. These can be called critical to quality engineering characteristics or CTQ ECs.

5 CONCLUSIONS

In determining the design requirements for machine flakes by using or implementing HOQ it produces recommendations and constraints that must be the main focus. HOQ which is a matrix of the relationship between CRs and ECs for designing machine flakes in the production process of banana flakes.

Distributing relative weight (%) scores shows scores ranging from lowest to highest for ECs. The higher the percentage of the relative weight obtained, the more ECs require special attention. HOQ matrix for flakes machine produces three main recommendations and constraints as explained in the discussion section that is the focus of design.



			Engineering Characteristics																	
Improvement Direction			↑	↓	↑			↑	↓	↓	↑	↓	↓	↑	↓		↓	↑	↓
Units			Kg/ batch	s	n/a	n/a	n/a	n/a	mm	kg	n/a	N	Hz	MPa	n/a	n/a	n/a	Pa.s	Kg/ m3
Costumer Requirements		Importance Weight Factor	Production capacity	Production time	Automation of machine	Material selection of machine	Manufacturing process selection	Safety factor	Dimension of machine	mass of machine	Life time	Force	Vibration frequency	Material strength	Energy consumption	Aesembly	Maintenance	product viscosity	Product density
Performance	Scaling up	4.6	9	9	3				9	1		1		1	1			1	3
	Reduce manual production process	4.4	3	9	9			9		1	1				3	3	3		
	Integrated with existing systems	4.4	9	9	9	1	1		3			1	1		3	9	3		
Durability	Continuously	4	9	9	9	3	1	9	1		9			3	9	3	3	1	1
Reliability	Operated for mushy and sticky dough	4.6	9	9	1	9	3				1	9		3	3		3	9	9
	Make the thin sheets dough	4.4	1	9			9		9		3	9		9	3		1	9	9
	Easy to use	4.6			9												1		
Features	Produce uniform products	4	9		3		3					3						3	
	Replace the manual flakes cutting	5	9	9	9	3	3	3	3	1	3	9		9	9	1	1	3	3
	Reducing the stages of the production process	4.4		9	9			1	3	1					9		3		
	Hygiene Products	4.8			3	9	3	3									3		
	Easy to carry and move	3.6					3		3	3						9	1		
Conformanc	Minimize noise	4				3	3	9			3		9	3		3	3	1	
	Energy saving	2.4		9	3	3						1			9				
Serviceability	Materials availability	1.4				9											3		
Raw Score		2557.8	257	343.8	293.2	147.8	126	145.4	137.2	29.2	85.2	149.4	40.4	127	200.2	114.2	113.6	120.6	113.8
Relative weight (%)		100	10.05	13.44	11.46	5.78	4.93	5.68	5.36	1.14	3.33	5.84	1.58	4.97	7.83	4.46	4.44	4.71	4.45
Rank Order			3	1	2	6	10	7	8	17	15	5	16	9	4	12	14	11	13

Figure 6: HOQ matrix for flakes machine in the banana flakes production process.

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