Quality improvement strategy of tofu stick production using fuzzy analytical hierarchy process (Case study in tofu stick SMEs cluster in Tinalan, Kediri)

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Abstract. Recent development of SMEs in Kediri is rapid, especially SMEs of local and creative food. Problem found in SMEs cluster of tofu stick is the difference of production process in each SMEs, so there are various quality of tofu stick. Therefore, it needs quality improvement to make the tofu stick product in accordance with quality standard (Indonesia National Standard/SNI) and consumers’ taste. Research objectives are to determine the best formula of tofu stick in Tinalan based on SNI using integration of consumer acceptance and laboratory test, and to determination quality improvement strategy alternatives using FAHP. Respondents consisted of 50 people for consumer acceptance test and 4 people as expert respondents. The results showed that the best formulas obtained are process improvement on a frying pan with first frying temperature 140±2°C in 22 seconds and second frying temperature is 200±2°C in 25 seconds, as well as packaging technique using the hot air temperature around the sealer. Average score of the consumer acceptance test was color (4.00), the uniformity of the form (4.16), crispness (4.00), smell (4.04) and taste (4.06) and in laboratory test for the Total Plate Count values appropriate with SNI of 3.0x102 colonies/g. The alternative strategy for increasing SMEs performances are to train of manpower, increase of information acces and enforce about partnerships.

1. Introduction
Kediri is one of the areas in East Java known as the City of Tofu. Tofu, basically, has a relatively short shelf life. Therefore, in order to lengthen its shelf life, tofu can be processed into various types of processed snacks. One of the processed food forms made from tofu is tofu stick. Tofu stick is a snack produced by slicing, drying and frying. This snack can be easily found in various souvenir centers in Kediri. Due to its high consumption rate, a lot of SMEs (Small and Medium Enterprises) have been established in Kediri. SME is a business that has a small to medium scale business that is seen from the number of workers, production capacity, number of assets, and size of business [10, 11]. According to the data taken from SMEs Agency of Kediri, there are 179 industries in food and
beverage sector. From those, 27 SMEs are producing tofu and its processed products. One of tofu sticks SMEs centers is in Tinalan village. There are 12 SMEs, five of which produce tofu stick were clustering in small (2 SMEs) and micro scale (3 SMEs). Clustering consists of a number of different methods for classifying similar objects into their respective categories and applies to broad research issues [1].

Nowadays, the market competition is getting tougher. Industries can survive in the market only if they are capable of producing quality products. Quality becomes the most important consumer decision for choosing a product. Product quality is a product or service characteristic that depends on its ability to satisfy the stated or implied consumer needs. To be able to survive in competition, SMEs should strive to meet the quality of tofu stick products to be accepted by consumers and to meet the existing quality requirements. An existing problem in tofu stick SMEs in Tinalan, Kediri is the non-uniformity of product quality, especially the colour and shape of tofu stick. This non-uniformity is mainly caused by manual production process of tofu stick due to limited cost and low production capacity. In addition, SMEs do not have standard operating procedures in the manufacture of tofu stick leading to incapability of producing quality tofu stick.

Fuzzy Analytical Hierarchy Process (FAHP) method was commonly used to determine the alternative strategy for improving the quality of tofu stick in SMEs in Tinalan. Critical Control Point (CCP) analysis was employed to determine the improvement process. Meanwhile, Effectiveness Index (EI) for consumer acceptance test (organoleptic test) and Multiple Attribute (MA) method for laboratory test were for to determine the best formula [12]. FAHP method is for to establish ranking or priority sequence of alternative problem solving and decision making [2]. With SMEs’ improvement of product quality as well as determination of appropriate improvement strategy, it is expected that SMEs can apply those aims to manufacture quality products, able to compete with similar products and accepted by the public.

2. Materials and methods

This research was conducted in five tofu stick SMEs in Tinalan, Kediri. The method of conducting the research are divided into consumer acceptance test and laboratory test of tofu stick in SME cluster, the first best treatment determination based from CCP analysis, the improvement of tofu stick process, consumer acceptance and laboratory test, the second best treatment determination and alternative strategy analysis for quality improvement. This study is conducted among 50 respondents filling out tofu stick organoleptic questionnaires and 5 expert respondents to fill out the questionnaire for determining the quality improvement strategy.

Determining the best formula can be completed by using EI is weighting procedure to determine the best treatment will be presented as follows:
1. Grouping parameters, physical parameters, and chemistry separated from organoleptic parameters
2. Giving each parameter a weight of 0-1 in each group
3. Effectiveness Value (EV) is calculated using the following formula:
   Greater average parameter is considered as better. The lowest value is as the worst value and the highest value as the best value
4. The calculation of Product Value (PV) is obtained from multiplication of EV with Weight Value
5. Product values of all parameters in each treatment group are calculated. The treatment that has the highest PV is the best treatment in the parameter group
The best treatment was chosen based on treatment having the highest PV for organoleptic parameters.

In laboratory test parameters, the best treatment/formula is determined by using MA [3]:
1. Determining ideal value of each parameter. Ideal value is expected value
2. Calculating degree of density
3. Calculating density range
With the assumption all parameters are important, the density range is calculated based on the number of parameters \( = \frac{1}{\text{number of parameters}} \). The best treatment is chosen from the alternatives having the smallest L1, L2 and L\(\infty\).

The completion stages using the FAHP are as follows [4]:
1. Organizing hierarchy. The problems to solve are broken down into elements, consisting of criteria and alternatives, and arranged into hierarchical structures.
2. Assessing criteria and alternatives. The criteria assessment is conducted to select the criteria considered important in choosing the best alternative.
3. Organizing hierarchy to various criteria and decision alternatives.
4. Forming pairwise comparison matrix. For each criterion and alternative, pairwise comparison is required. Comparative values are then processed to determine the relative ranking of all alternatives.
5. Consistency testing. In pairwise comparison examination, inconsistencies from opinions/preferences given by decision makers are often occur. The consistency of paired assessments is evaluated by calculating Consistency Ratio (CR). If CR is ≤ 0.1, then the assessment results are considered as consistent.
6. Weighting criteria and alternatives using fuzzy synthetic

3. Results and discussion
Kediri is popular with tofu production and the center of cluster in Tinalan Village have 5 SMEs, with the profiles are presented in Table 1.

| SMEs | Types of soybean | Capacity (kg/month) | Number of workers | Selling price (IDR/100g) | Sales turnover (IDR/month) |
|------|------------------|---------------------|-------------------|--------------------------|---------------------------|
| A    | Local            | 420                 | 2                 | 9,000                    | 2.7                       |
| B    | Local            | 300                 | 2                 | 8,000                    | 4.8                       |
| C    | Local            | 300                 | 3                 | 9,000                    | 18.9                      |
| D    | Local            | 420                 | 2                 | 9,000                    | 23.2                      |
| E    | Local            | 255                 | 2                 | 10,000                   | 2.4                       |

Based on Table 1, all SMEs use local soybean for tofu stick production. The average daily soybean feedstock for SMEs in Tinalan is estimated need of soybean around 333 kg/month. The average number of workers in each SME consists of 2 to 3 people. The selling price per 100 gram of tofu stick starts from IDR 8,000 to 10,000 depending on individual SMEs policy. The previously presented data are used to classify SMEs into groups (clusters). According to Chang [4], cluster analysis is a statistical technique devoted to classify units into groups.

3.1. Determining of the best formula
In determining the first best formula of tofu stick, it was initiated with consumer acceptance test using organoleptic test against color parameters, uniformity of shape, crispness, aroma and taste. The test results were then analyzed using EI method. The results of consumer acceptance test and EI 1st calculation can be seen in Table 2 and Figure 1.
Table 2. Test result of consumer acceptability 1st.

| Parameter          | SMEs | A   | B   | C   | D   | E     |
|--------------------|------|-----|-----|-----|-----|-------|
| Color              |      | 3.30| 3.14| 3.00| 3.06| 3.48* |
| Shape uniformity   |      | 3.22| 3.20| 3.16| 3.70*| 3.26  |
| Crispness          |      | 2.58| 3.40| 2.72| 3.94| 3.04  |
| Flavor             |      | 3.20| 2.96| 3.04| 3.80*| 3.20  |
| Taste              |      | 3.30| 3.34| 3.00| 4.16*| 3.28  |

Figure 1. EI analysis

Based on the results of EI analysis in Figure 1, it can be concluded that the best product based on consumer acceptability is obtained by SMEs “D” with the highest product value of 0.84. The highest parameters obtained were taste parameter; meanwhile, color parameters get the second lowest value among other SMEs. The preferable color the consumer wants is a tofu stick with a yellowish white color. Multiple Attribute (MA) method was also employed in laboratory test, complimenting EI method, to determine the best formula. MA is a part of decision making, usually referring to a single goal, selection of the best alternative and some constraints or attributes [8]. MA is important for determining decision-making in many contexts using quantitative data. Laboratory test results and MA calculations are presented in Table 3 and Figure 2.

Table 3. Results of laboratory test 1st.

| Parameter         | SMEs | A   | B   | C   | D   | E   |
|-------------------|------|-----|-----|-----|-----|-----|
| Water content (%) |      | 2.02| 2.03| 3.03| 1.91| 1.82|
| Protein content (%)|     | 39.05| 35  | 32.98| 30.76| 28.47|
| ALT (colony)      |      | 1.3x10^2| 3.0x10^1| 4.0x10^2| 6.0x10^2^| 9.0x10^1^|
Based on the results of Multiple Attribute analysis in Figure 3, the best formula is obtained by SMEs “B” with the lowest density distance of 0.6204. Based on EI analysis, SMEs “D” shows the best treatment. It is therefore necessary to integrate between two SMEs by conducting EI re-analysis of SMEs “B” and “D”. The result of EI re-analysis are SMEs “D” attains the highest product value is approach to determine as the first best. On the other hand, WK produces undesirable tofu stick color not matching with the consumers’ taste, wanting a yellowish white color while its color is still golden yellow. This golden yellow color is influenced by a browning reaction (Maillard). According to Pearce et al. [9], Maillard reaction occurs during the cooking process and causes discoloration, flavour and aroma alterations. Moreover, by having TPC value of 6.0x10², it does not meet the existing quality requirements. The quality requirement used in tofu stick is SNI 01-4470-1998 presented in Table 4.

### Table 4. Quality requirement of tofu stick.

| Test criteria                  | Unit | Standard |
|-------------------------------|------|----------|
| Organoleptic                  |      |          |
| 1.1. Odor                      | -    | Normal   |
| 1.2. Taste                     | -    | Normal   |
| Water content (b/b)            | %    | Max. 10.0|
| Protein content (b/b)          | %    | Max. 10.0|
| Ash content (b/b)              | %    | Max. 2.0 |
| Microbial contaminant          |      |          |
| 5.1. Total plate number        | colony/g | Max. 4x10² |
| 5.2. Escherichia coli          | APM/g | Max. 3   |
| 5.3. Salmonella                | Per 25 g | Negative |

Source: SNI 01-4470-1998 (http:/sisni.bsn.go.id)

### 3.2. Process improvement

Process Improvement is employed to obtain product characteristics to meet with applicable standards, improving the product quality. CCP analysis is performed before conducting quality improvement. CCP is a point or stage where controls can be applied so that food hazards can be prevented, eliminated or reduced to acceptable levels. Initially, consumers will interested in color as the first appealing characteristic of the tofu, causing color becomes the most important characteristic to be considered in tofu stick production. Color is affected by frying process. The combination of yellowish white color is favoured by consumers. It can be achieved the temperature is lowered producing a
rather pale color. On the other hand, higher frying temperature will cause and produce a slightly brownish color. The incidence of brownish color on the surface of the material is caused by the browning reaction or Maillard reaction. Maillard reaction is a non-enzymatic reaction between sugars and amino acids that causes turn to brown. Maillard reaction has a positive and negative impact. Although it has negative impacts, it is not harmful to health. The main factors affecting color, taste and odor are the types of cooking oil, the temperature of oil storage, the temperature and duration of frying, the size, moisture and appearance of the food and the treatment after frying [8]. The laboratory parameter shows that the TPC value of tofu stick has not met the quality requirements. It is influenced by the packaging process. A good packaging process will affect the shelf life of the product. The process improvement was performed with 2 alternative treatments possible to select in Table 5.

| Tabel 5. Improvement process alternatives of tofu stick. |
| --- |
| Treatment | Description |
| I | First frying on temperature of 140±2°C for 22 seconds and second frying on temperature of 200±2°C for 25 seconds. |
| II | First frying on temperature of 140±2°C for 22 seconds and second frying on temperature of 180±2°C for 25 seconds. |

After completing the process improvement using two treatments, the product improvement was re-tested in the organoleptic test and laboratory test and then analyzed using Effectiveness Index and Multiple Attribute to achieve the second best formula. The results of consumer acceptance test can be seen in Table 6. The results of laboratory tests can be seen in Table 7. Based on the results of EI and MA, the best formula was discovered on the first treatment (P1). P1 shows the color organoleptic results (4.00), shape uniformity (4.16), crispness (4.00), aroma (4.04) and taste (4.06). The laboratory test results present 2.91% moisture content, 36.37% protein content and TPC 3.0x10².

| Table 6. Test result of consumer acceptance 2nd. |
| --- |
| Parameter | SMEs “D” | Treatment |
| Color | 3.06 | 4.00* | 3.48 |
| Form uniformity | 3.70 | 4.16* | 3.64 |
| Crispness | 3.94 | 4.00* | 3.70 |
| Flavor | 3.80 | 4.04* | 3.48 |
| Taste | 4.16 | 4.06* | 3.70 |

| Table 7. Laboratory test result 2nd. |
| --- |
| Parameter | SMEs “D” | Treatment |
| Water content (%) | 1.91 | 2.91 | 3.06 |
| Protein content (%) | 30.76 | 36.37 | 33.86 |
| ALT | 6.0x10² | 3.0x10² | 3.0x10² |

3.3. Determining strategy of quality improvement using FAHP

After obtaining the second best formula, determining the strategy of quality improvement of tofu stick production process becomes the following step. This strategy is obtained from the analysis by FAHP method. FAHP is a method derived from AHP method and then combined with fuzzy. FAHP is used to determine the decision making.

This research uses two variables, raw material and production process variable. In addition, it employs three alternative strategies, training workers, improving access to information and establishing partnerships. Fuzzy AHP is a method used to determine the importance level of a chosen
strategy. The use of this method is more direct than that of the previous method (AHP). Based on the calculation using FAHP method, the weight value of each variable and alternative strategy on improving the quality of tofu stick production process can be obtained, illustrated in Table 8.

| Strategy alternative | Raw material Weight (0.297) | Production Weight (0.695) |
|----------------------|-----------------------------|--------------------------|
| Labor training       | 0.325                       | 0.373                    |
| Partnership          | 0.292                       | 0.302                    |
| Improvement on information access | 0.368                     | 0.318                    |

Based on the previous hierarchy structure, to improve the quality of a tofu stick product, variables which essential to be considered are the variables of production process having a weight value of 0.695. It means that the variables of production process more important than variables of raw material. The alternative strategies obtained in this study is weighted from the highest to the lowest values, labor training of 0.356, increasing access to information of 0.330 and establishing partnership of 0.297. To improve the quality of tofu stick on SMEs “D”, the production process of tofu stick on SMEs should be improved by labor training to improve their skills producing tofu stick to meet the consumer satisfaction and the existing quality requirements. The most important object focus for controlling production activities is labor. However, humans can also cause problems in controlling the production process.

4. Conclusion
The result of the first best formula determination based on the results of consumer acceptance test using EI and laboratory test using MA in SMEs cluster tofu stick is SMEs “D”. The organoleptic color is still relatively low, and the laboratory test parameters of Total Plate Count (TPC) do not meet the quality requirements. The second best formula after improvement process, produced on the tofu stick samples of treatment 1st with the results of laboratory tests shows a changing parameter value of Total Plate Count which meets the quality requirement of SNI 01-4470-1998 for stick. The strategy of quality improvement in tofu stick production process obtained the highest weight on production process variables using strategy of labor training, improving access to information and establishing partnership.

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