Best Concept Selection for Dry-Soybean Cracking Machine Process Optimization using TOPSIS method

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Abstract. Tempe is a traditional Indonesian food with processed soybean as the main ingredients. Indonesia is the largest tempe producer in the world with hundreds of thousands of traditional tempe maker. Currently the traditional production process is wasteful that requires the amount of water as much as 1321 liters/production of 37.5 kg tempe. Innovative dry production process is still less desirable because the dry soybean cracker machine is not optimal with a defect of 14.4% per production. In addition, the machine is unable to separate the husk and soybeans from the outlet. There are 12 alternative production concepts to produce highest quality tempe. TOPSIS method was used for selecting best production concept which reduces defect to 6.5% while manual separation process is eliminated. Water consumption is reduced to 800 liters/production of 35,125 kg tempe.

Keywords: TOPSIS, concept selection, dry-soybean

1. Introduction
SME (Small Medium Enterprise) sector which contribute big enough for Indonesia Gross Domestic Product in food field is tempe craftsmen. The average tempe consumption per person per year in Indonesia has reached 6.95 kilograms in 2014 [1]. The level of tempe consumption in Indonesia can be seen from the high volume of soybean imports by Indonesia as shown in Figure 1 [2].

![The soybean import volume of Indonesia, 2009-2013](image)

Figure 1. The soybean import volume of Indonesia, 2009-2013
Production process commonly done by tempe craftsmen in Indonesia is wet production process. This process requires a total water supply of 1321 liters per production, with the description as in Table 1 below.

| Wet Process                                | Amount of water (liter) |
|--------------------------------------------|------------------------|
| Soybeans boiling                           | 300                    |
| Soybeans soaking                           | 300                    |
| Soybeans cracking                          | 471                    |
| Soybeans washing to separate husks         | 250                    |
| Soybeans drying                            | 0                      |
| Giving yeast                               | 0                      |
| Fermentation                               | 0                      |
| **Total**                                  | **1321**               |

To minimize the amount of water that is used along the production, there is another production process that is dry process. This process requires only 800 liters of water per production. Dry production process is shown in Figure 2.

![Flow process of tempe dry production](image)

**Figure 2.** Flow process of tempe dry production

Based on the dry production process flow diagram of tempe in Figure 2, it is known that the initial step is cracking the soybean into two parts, which is an important process in making tempe. This step is important because when the soybean is cracked, there will be several conditions that will happen and affect the next processes. First condition as targeted, soybeans are divided into two and the husk are detached. Secondly, soybeans may be divided into two but the husks still attached, this condition will inhibit the fermentation process. And thirdly, soybeans are crushed into powder that can’t be used for tempe production. By using the existing machine, there are two main problems for this process that cause the low implementation of this process in tempe production in Indonesia. The first problem is that there is a defect of 14.5% and the husks are still mixed 100% with soybean cracking results out of the outlet, so it needs extra process to separate the husks manually by sifting. The separation of the husks of soybean is important because it aims to make the yeast infiltrate the entire soybean in order to produce good tempe [3].

In order to optimize the performance of dry crusher machine, then these studies do the selection of the concept of crusher machine that can be done optimally. In product development, there are various stages to be implemented. However, the conceptualization stage of the product is a key stage in the product development which is divided into two activities; concept generation and concept selection [4]. In this research, the method used for concept selection is TOPSIS (Technique for Order of Preference
by Similarity to Ideal Solution) method. TOPSIS method is chosen because it considers both ideal and anti-ideal concepts [5].

![Figure 3. Existing dry soybean cracking machine](image)

2. Methods

2.1. TOPSIS (Technique For Order Of Preference By Similarity To Ideal Solution)

Multiple Criteria Decision Making or Multiple Criteria Decision Analysis (MCDA) was developed by Hwang dan Yoon. MCDM used for decision making with various criteria, which are usually contradictory [6]. This method was developed to choose the best alternative based on various criteria which is the integration of finance factor and external factor related to performance. There are many approaches to MCDA, each involving different scientific procedures for generating inputs, structures to represent, combining algorithms, and processes for interpreting and using formal results in the context of providing advice or decision making [7]. One method used as an approach for multiple criteria decision making is TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method. Alternative selection using TOPSIS method is based on the assumption that the best alternative has the shortest Euclidean distance from the positive ideal solution (consisting of the best value for each attribute regardless of the alternative) and has the furthest distance from the negative ideal solution (comprising the worst value) [8]. TOPSIS method has been widely used in various fields ranging from those related to machine tool selection [9], sustainable energy alternatives [10], to car beam bumper [11].

2.2. TOPSIS method’s stages

In general, TOPSIS method has three main stages involved in the evaluation phase [12], which are determining the criteria of selection and alternative design concepts, determining the importance of each criterion and the effect of alternatives on the criteria, and calculating the ranking of all alternatives using the TOPSIS algorithm.

1) At this stage, alternative combinations of concepts from several sub-solutions to the design objectives are generated. After generate the sub solutions, not all of the concepts are screened and scored but only the feasible concepts [13]. The combination of possible concepts is 12 concepts...
from concept A to L. After that, the selection criteria are determined based on the design objectives, and the weights based on the level of importance given by the customer/user via questionnaire [14].

(2) The initial stage of TOPSIS method is to create a table that contains the value of each concept against each criterion. Because there are three assessment criteria that have a type of qualitative assessment. Thus, it needs to be converted to quantitative by determining a range of relative values from one to five [12]. The values given in Table 2 for each criterion can be written using each unit or relative performance’s rating [12].

(3) Normalization of decision matrix can be done by determining normalized rating like the following formula.

\[ n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m}x_{ij}^2}} \quad i = 1, ..., m, \quad j = 1, ..., n \]  

(4) The weighting for normalized decision matrix can be done with the following formula.

\[ V = N_D \cdot W_{nxn} = \begin{bmatrix}
V_{11} & V_{1j} & \cdots & V_{1n} \\
\vdots & \vdots & \ddots & \vdots \\
V_{m1} & V_{mj} & \cdots & V_{mn}
\end{bmatrix} \]  

Where \( w_j \) is the weight of the \( i \)-th criterion, and \( \sum_{j=1}^{m} w_j = 1 \).

(5) To calculate the value of positive ideal solution (PIS) and negative ideal solution (NIS), using the following formula.

\[ A^+ = \begin{bmatrix}
\left( \max_j v_{ij} \right)_{i \in I} \\
\left( \min_j v_{ij} \right)_{i \in J}
\end{bmatrix} \quad \text{and} \quad I \text{ is for criteria related to profit or benefit, and } J \text{ is for criterion related to cost.} \]

\[ A^- = \begin{bmatrix}
\left( \min_j v_{ij} \right)_{i \in I} \\
\left( \max_j v_{ij} \right)_{i \in J}
\end{bmatrix} \]

(6) The distance of each alternative from the positive ideal solution is calculated as follows.

\[ d_{i}^+ = \left\{ \frac{1}{2} \sum_{j=1}^{n} (v_{ij} - v_{ij}^+)^2 \right\}^{1/2} \]

Then, the distance of each alternative from the negative ideal solution is calculated as follows.

\[ d_{i}^- = \left\{ \frac{1}{2} \sum_{j=1}^{n} (v_{ij} - v_{ij}^-)^2 \right\}^{1/2} \]

(7) The relative closeness value for alternative \( Ai \) to \( A^+ \) is defined by the following equation.

\[ cl_{i} = \frac{d_{i}^+}{d_{i}^+ + d_{i}^-} \quad \text{for } 0 \leq cl_{i} \leq 1 \]

After getting the relative closeness value, then all alternatives are sorted according to the highest to lowest value as in Table 7.

| No. | Concept | The machine could crack the soybean optimally | The hopper could discharge the soybean optimally | The machine could separate the cracked-soybean and husk | The machine could work optimally with efficient electricity power |
|-----|---------|---------------------------------------------|---------------------------------------------|------------------------------------------------|-------------------------------------------------|
| 1   | A       | 4                                           | 4                                           | 4                                              | 0.33                                            |
| 2   | B       | 4                                           | 4                                           | 5                                              | 0.73                                            |
| 3   | C       | 5                                           | 4                                           | 4                                              | 0.33                                            |
| 4   | D       | 5                                           | 4                                           | 5                                              | 0.73                                            |
| 5   | E       | 4                                           | 4                                           | 4                                              | 0.33                                            |
| 6   | F       | 4                                           | 4                                           | 5                                              | 0.73                                            |
| 7   | G       | 5                                           | 4                                           | 4                                              | 0.33                                            |
| 8   | H       | 5                                           | 4                                           | 5                                              | 0.73                                            |
| 9   | I       | 4                                           | 5                                           | 4                                              | 0.33                                            |
| 10  | J       | 4                                           | 5                                           | 5                                              | 0.73                                            |
The machine could optimally crack the soybean and separate the cracked soybean and husk. The hopper could optimally discharge the soybean. The machine could work optimally with efficient electricity power.

| No. | Concept | The machine could crack the soybean optimally | The hopper could discharge the soybean optimally | The machine could separate the cracked soybean and husk | The machine could work optimally with efficient electricity power |
|-----|---------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------|
| 1   | A       | 1,37,E-03                                     | 1,48,E-03                                     | 1,37,E-03                                           | 8,16,E-03                                                     |
| 2   | B       | 1,37,E-03                                     | 1,48,E-03                                     | 1,71,E-03                                           | 1,80,E-02                                                     |
| 3   | C       | 1,71,E-03                                     | 1,48,E-03                                     | 1,37,E-03                                           | 8,16,E-03                                                     |
| 4   | D       | 1,71,E-03                                     | 1,48,E-03                                     | 1,71,E-03                                           | 1,80,E-02                                                     |
| 5   | E       | 1,71,E-03                                     | 1,48,E-03                                     | 1,37,E-03                                           | 8,16,E-03                                                     |
| 6   | F       | 1,71,E-03                                     | 1,48,E-03                                     | 1,71,E-03                                           | 1,80,E-02                                                     |
| 7   | G       | 1,71,E-03                                     | 1,48,E-03                                     | 1,37,E-03                                           | 8,16,E-03                                                     |
| 8   | H       | 1,71,E-03                                     | 1,48,E-03                                     | 1,71,E-03                                           | 1,80,E-02                                                     |
| 9   | I       | 1,71,E-03                                     | 1,85,E-03                                     | 1,37,E-03                                           | 8,16,E-03                                                     |
| 10  | J       | 1,71,E-03                                     | 1,85,E-03                                     | 1,71,E-03                                           | 1,80,E-02                                                     |
| 11  | K       | 1,71,E-03                                     | 1,85,E-03                                     | 1,37,E-03                                           | 8,16,E-03                                                     |
| 12  | L       | 1,71,E-03                                     | 1,85,E-03                                     | 1,71,E-03                                           | 1,80,E-02                                                     |

Table 4. Weighted normalized decision matrix

| Concept | The machine could crack the soybean optimally | The hopper could discharge the soybean optimally | The machine could separate the cracked soybean and husk | The machine could work optimally with efficient electricity power |
|---------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------|
| A       | 2,47,E-04                                     | 3,55,E-04                                     | 3,98,E-04                                           | 2,37,E-03                                                     |
| B       | 2,47,E-04                                     | 3,55,E-04                                     | 4,97,E-04                                           | 5,23,E-03                                                     |
| C       | 3,09,E-04                                     | 3,55,E-04                                     | 3,98,E-04                                           | 2,37,E-03                                                     |
| D       | 3,09,E-04                                     | 3,55,E-04                                     | 4,97,E-04                                           | 5,23,E-03                                                     |
| E       | 2,47,E-04                                     | 3,55,E-04                                     | 3,98,E-04                                           | 2,37,E-03                                                     |
| F       | 2,47,E-04                                     | 3,55,E-04                                     | 4,97,E-04                                           | 5,23,E-03                                                     |
| G       | 3,09,E-04                                     | 3,55,E-04                                     | 3,98,E-04                                           | 2,37,E-03                                                     |
| H       | 3,09,E-04                                     | 3,55,E-04                                     | 4,97,E-04                                           | 5,23,E-03                                                     |
| I       | 2,47,E-04                                     | 4,44,E-04                                     | 3,98,E-04                                           | 2,37,E-03                                                     |
| J       | 2,47,E-04                                     | 4,44,E-04                                     | 4,97,E-04                                           | 5,23,E-03                                                     |
| K       | 3,09,E-04                                     | 4,44,E-04                                     | 3,98,E-04                                           | 2,37,E-03                                                     |
| L       | 3,09,E-04                                     | 4,44,E-04                                     | 4,97,E-04                                           | 5,23,E-03                                                     |

Table 5. Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS)

| Concept | The machine could crack the soybean optimally | The hopper could discharge the soybean optimally | The machine could separate the cracked soybean and husk | The machine could work optimally with efficient electricity power |
|---------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------|
| PIS     | 4,46,E-04                                     | 3,88,E-04                                     | 4,46,E-04                                           | 2,12,E-03                                                     |
| NIS     | 3,57,E-04                                     | 3,11,E-04                                     | 3,57,E-04                                           | 4,69,E-03                                                     |

Table 6. Distance every alternatives with ideal solution

| Concepts | A      | B      | C      | D      | E      | F      |
|----------|--------|--------|--------|--------|--------|--------|
| $d_{i+}$ | 2,16,E-08 | 8,24,E-06 | 1,78,E-08 | 8,23,E-06 | 2,16,E-08 | 8,24,E-06 |
| $d_{i-}$ | 8,22,E-06 | 9,89,E-09 | 8,23,E-06 | 1,37,E-08 | 8,22,E-06 | 9,89,E-09 |
| Concepts | G      | H      | I      | J      | K      | L      |
|----------|--------|--------|--------|--------|--------|--------|
| $d_{i+}$ | 1,78,E-08 | 8,23,E-06 | 1,37,E-08 | 8,23,E-06 | 9,89,E-09 | 8,22,E-06 |
Table 7. Relative closeness value

| Concept | A   | B   | C   | D   | E   | F   |
|---------|-----|-----|-----|-----|-----|-----|
|          | $c_{I_i}$+ | 9.97,E-01 | 1.20,E-03 | 9.98,E-01 | 1.66,E-03 | 9.97,E-01 | 1.20,E-03 |
| Concept  | G   | H   | I   | J   | K   | L   |
|          | $c_{I_i}$+ | 9.98,E-01 | 1.66,E-03 | 9.98,E-01 | 2.15,E-03 | 9.99,E-01 | 2.62,E-03 |

3. Result and Discussion

Based on data processing and analysis, result is obtained, refers to the purpose of research, which is to support the process of dry soybean breaking to be more optimal, then the concept of dry soy crusher machine selected is the concept of K with the value of relative closeness 9.99, E-01. Which means concept K is relatively considered has the most ideal closeness value to ideal and non-ideal solution, compared to other alternative concepts. The K concept has a conical hopper shape for the mass flow product outflow connected with a single pitch, single flight screw conveyor. The diameter of the grinding wheel is 200 mm with 1 mm distance that adjust by T-handle type of adjuster fitted with a distance label that makes the distance adjustment process more accurate. The grinding wheel of the rotor is driven by a ¼ HP electrical motor and power is transmitted using a belt drives transmission system. In order for the product and the residue to be separated simultaneously upon the outlet, the machine is provided with a blower separator of the 2 "hole diameter output hole. The product and the residue will come out on a separate path because the channel is branched off.

4. Conclusion

The existing dry soybean cracker machine used by most traditional tempe craftsmen still can not work optimally. So, in this study, the selection of design concept of dry soybean breaker machine to get the concept with a combination of components that are more optimal than the existing machine is conducted. The K concept has been chosen after being compared to the other eleven concepts. This concept has an adjustable distance for achieving optimum parameters with ease, a hopper that has an optimum diameter so that the soybean distribution becomes better. The selected machine is also able to separate soybean products and husks simultaneously so that manual separation process can be eliminated. Although the addition of the separator blower to separate the product and the skin means adding to the required electrical power requirements, but compared to existing machines on the market, the total power required is still lower. With the proposed machine, the defect percentage of tempe production using dry-soybean cracking machine could be decreased to 6.5% from 14.4% and the amount of water needed compared to wet process is decreased also to 800 liters/production of 35,125 kg tempe from 1321 liters/production of 37.5 kg tempe. In addition, the authors suggest that subsequent studies should be tested for selected concepts in order to verify the consequences of a combination of selected concept components that may occur.

5. References

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