Efficiency analysis of tempeh chips production using a data envelopment analysis

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Abstract. The Small Medium Enterprises (SMEs) clusters of tempeh chips face critical problems in the production process, i.e., the low quality of raw materials, defective products, and fluctuating sales. These issues affect their productivity, leading to impending improvements. One effort to increase productivity is to increase efficiency during the production process. The research objectives are to analyze and improve the efficiency of soybean chips production using Data Envelopment Analysis (DEA). The objects of research are 5 SMEs that are producing tempeh chips in the same classification. The results showed that the efficiency of production variables are losses, labor, and sales results. The efficiency value is 89.4% -100%, which shows that the production process runs inefficiently due to the high number of losses during the production process, inaccurate production targets, low product selling prices, and limited marketing. The suggested improvement for industries is to improve raw material planning and employee performance to reduce the number of losses that occurred, evaluate and upgrade the supply chain management, optimize social media marketing, and increase the competitiveness of tempeh chips products.

1. Introduction
Tempeh is a traditional fermented food made from soybeans [1]. Processing tempeh into tempeh chips can increase its selling value and extend the shelf life [2]. Sanan is one of the industrial centers in Malang City, producing tempeh chips with 308 business units [3]. Tempeh chips are also superior-typical food products of Malang City. The increasing number of domestic tourists in Malang City, reaching 77% in 2015 [4], escalated the potency of business development for tempeh chips for SMEs actors. The ability of business actors to see existing opportunities is one of the main keys to business development. Furthermore, it is also supported by the increased knowledge of business actors to improve the efficiency of product development processes and management within the organization [5].

This study used 5 SMEs, which belong to 1 cluster. A cluster is a group of companies involved in similar or interrelated economic activities in a particular economy [6]. An industrial cluster is a concentration of interdependent companies, such as suppliers, producers, traders, and users, located in a geographic area to produce the same or closely related goods. The five SMEs have an average production capacity of 200 pcs of packaging per day by processing 50-80 kg of tempeh, and their marketing areas cover Java and Bali. The width of the marketing area and the increasing number of
product requests are the strong reasons for SMEs always maintaining product quality and increasing productivity to preserve consumer trust. Additionally, improving the production efficiency through performance can escalate productivity so as the production result is more significant than the resources used [7]. The process improvement making it better and safer indicates that it has run effectively [8].

Problems found in the production process at the Sanan tempeh chips industry cluster were the low quality of raw materials, the emergence of defective products, and volatile sales volumes. Defects are caused by the slicing process (inappropriate shape), frying (overlong frying time), and improper packaging. Moreover, inadequate system planning and the availability of facilities will impact the final product result [9]. Activities causing waste need to be fixed, for they influence the amount of production [10]. The implementation of ineffective marketing strategies leads to volatile sales resulting in low production process efficiency. Problems arising during the production process often come from raw materials, workers, machines, and facilities. Therefore, it needs an analytical approach to increase or maximize efficiency during the production process. One approach that can be used to analyze efficiency is Data Envelopment Analysis (DEA) [11]. Measurement of efficiency level using DEA method has three advantages; to determine relative efficiency value to ease comparing each DMU, to measure entire output and the input value of each DMU, and it does not need a parametric specification of a functional form [12]. This study aims to analyze the efficiency of the tempeh chips production process and provide suggestions for improvements to increase efficiency using the DEA approach.

2. Research methods

The research locations were 5 SMEs members of the tempeh chip industry cluster in Sanan, Blimbing, Malang City, East Java, Indonesia. The research was conducted with input orientation using the Bhanker, Charnes, and Cooper (BCC) Data Envelopment Analysis (DEA) model. The object used in this research is the production process in five industries located in the Sanan tempeh chips industry cluster, Malang. The 5 industries are Dua Karunia, Kiki, Amel, Asri, and Ones. The sizes of some of these industries are almost the same, so they are categorized in the category of small industrial scale, referring to Indonesian Law no. 20/2008. The research data taken was from January to December 2018 (12 months or a production period of 1 year), so there were 60 cases studied.

The Data Envelopment Analysis (DEA) method is a multivariable input and output analysis method to measure the efficiency of a group of Decision-Making Units (DMU). The DMU used is a unit with homogeneous properties and the same input and output variables. DMU classification in this study can be seen in Table 1 and the operational definition of input and output variables in Table 2.

| Table 1. The classification of DMU. |
|-------------------|-------------------|
| Object            | DMU               |
| Dua Karunia       | DMU1              |
| Kiki              | DMU2              |
| Amel              | DMU3              |
| Asri              | DMU4              |
| Ones              | DMU5              |

| Table 2. The operational definition of input and output variables. |
|---------------------|------------------|-----------------|----------------|
| No  | Sub criteria | Symbol | Unit | Criteria | Information |
|-----|-------------|--------|------|----------|-------------|
| 1   | Raw material cost | X1 | IDR | Input | The cost of the main raw material (soybeans) during the production process in 1 month |
| 2   | Labor costs  | X2 | IDR | Input | The number of labor costs in 1 month |
The above equation is the DEA BCC-I equation which is used to determine the Decision-Making Unit (DMU), which is efficient (=1) and which is inefficient (<1). The Banxia Frontier Analysis software assists the efficiency calculation.

3. Results and discussion
The tempeh chips production process is carried out through a continuous process, namely a production system that runs continuously in relatively short production intervals and relatively steady production quantity. Various manufacturing industry sectors have adopted continuous manufacturing processes that create commodity products such as food, chemicals, and pharmaceuticals product [13]. Efficiency measurement of the tempeh chips production process was carried out using the Data Envelopment Analysis (DEA) method. The input and output variable data used in the efficiency calculation are the production process data in 1 year (2018), and the efficiency calculation results can be seen in Table 3.
### Table 3. The results of efficiency calculation.

| No. | DMU  | Month | Score (%) | Condition | Information |
|-----|------|-------|-----------|-----------|-------------|
| 1.  | DMU1 | 01    | 95.8      | Amber     | Inefficient |
|     |      | 02    | 100       | Green     | Efficient   |
|     |      | 03    | 100       | Green     | Efficient   |
|     |      | 04    | 95.6      | Amber     | Inefficient |
|     |      | 05    | 100       | Green     | Efficient   |
|     |      | 06    | 100       | Green     | Efficient   |
|     |      | 07    | 98.2      | Amber     | Inefficient |
|     |      | 08    | 100       | Green     | Efficient   |
|     |      | 09    | 95.3      | Amber     | Inefficient |
|     |      | 10    | 94.7      | Amber     | Inefficient |
|     |      | 11    | 96.7      | Amber     | Inefficient |
|     |      | 12    | 98.3      | Amber     | Inefficient |
| 2.  | DMU2 | 01    | 100       | Green     | Efficient   |
|     |      | 02    | 100       | Green     | Efficient   |
|     |      | 03    | 95.3      | Amber     | Inefficient |
|     |      | 04    | 95.3      | Amber     | Inefficient |
|     |      | 05    | 98.0      | Amber     | Inefficient |
|     |      | 06    | 92.9      | Amber     | Inefficient |
|     |      | 07    | 100       | Green     | Efficient   |
|     |      | 08    | 95.3      | Amber     | Inefficient |
|     |      | 09    | 95.3      | Amber     | Inefficient |
|     |      | 10    | 100       | Green     | Efficient   |
|     |      | 11    | 96.9      | Amber     | Inefficient |
|     |      | 12    | 100       | Green     | Efficient   |
| 3.  | DMU3 | 01    | 96.0      | Amber     | Inefficient |
|     |      | 02    | 100       | Green     | Efficient   |
|     |      | 03    | 99.7      | Amber     | Inefficient |
|     |      | 04    | 96.9      | Amber     | Inefficient |
|     |      | 05    | 100       | Green     | Efficient   |
|     |      | 06    | 97.5      | Amber     | Inefficient |
|     |      | 07    | 99.8      | Amber     | Inefficient |
|     |      | 08    | 93.9      | Amber     | Inefficient |
|     |      | 09    | 96.8      | Amber     | Inefficient |
|     |      | 10    | 98.7      | Amber     | Inefficient |
|     |      | 11    | 100       | Green     | Efficient   |
|     |      | 12    | 94.9      | Amber     | Inefficient |
| 4.  | DMU4 | 01    | 92.2      | Amber     | Inefficient |
|     |      | 02    | 100       | Green     | Efficient   |
|     |      | 03    | 100       | Green     | Efficient   |
|     |      | 04    | 96.3      | Amber     | Inefficient |
|     |      | 05    | 93.3      | Amber     | Inefficient |
|     |      | 06    | 100       | Green     | Efficient   |
|     |      | 07    | 100       | Green     | Efficient   |
|     |      | 08    | 100       | Green     | Efficient   |
|     |      | 09    | 100       | Green     | Efficient   |
The outputs of the efficiency analysis (Table 3) of the Banxia Frontier Analysis software are amber and red, meaning inefficient process, and green means efficient [14]. During 2018, it was found that the production process ran inefficiently at 58.3% (56.6% amber and 1.7% red), and the rest, 41.7% of the production process, ran efficiently. The efficiency shows the performance of a unit in producing output using the existing resources [15]. SMEs “DMU3” became the DMU with the most production inefficiencies in 2018 for 9 months (75%). SMEs “DMU1” became DMU whose production process was most efficient in 2018 for 6 months (50%). The lowest efficiency score of the five DMUs was found in the SMEs “DMU4” with a score of 89.4% (red condition). The causative factor for the company to run inefficiently was the performance of untrained human resources and caused a lot of waste during work [16].

The tempeh chips production inefficiencies mostly occur in March, April, and before the new year in December. The lowest efficiency value is found in SMEs “DMU4” of 89.4% (red condition). Based on the conditions in the field, the quality of the tempeh raw materials used in those months was not so good. The texture of tempeh was softer and less dense, so the tempeh slices became more frangible, crumbly (seeds are easy to fall out, do not stick firmly), and did not meet the criteria. The factor causing the low quality of raw materials in conditions of production inefficiency is the high rainfall, which impacts the low quality of tempeh. The high humidity level inhibits the growth of molds that plays a major role in the tempeh fermentation process caused the texture and structure were not solid, and tempeh was not perfectly bound by mold (easy to fall off). In general, tempeh production was carried out by home-scale business actors using a fermentation process that was not well controlled. By Controlling fermentation process and a suitable environment, will help the growth of fungi during the fermentation process. The fungi bind the individual soybean seeds into a dense, sliceable shape. One way to improve tempeh quality is starting from the production of starter culture during the tempeh fermentation stage [17].

The production inefficiency experienced by SMEs "DMU1" requires the SMEs to reduce their production capacity. It aims to reduce the possibility of losses that occurred due to the quality of raw materials that do not meet the requirements. This can also be seen from the results of the SMEs "DMU1" which is more efficient than other DMUs. The SMEs “DMU3” and "DMU2" also have a fairly high number of losses. DMU with a relative efficiency score of less than 100% can be categorized as inefficient. This is because in the condition of low raw material quality, both remain to carry out the production process in the same amount to meet the retailers’ demand. Inefficient DMU indicates excessive use of inputs, and it must be reduced according to the amount needed so producers can create efficiencies and develop better products [18].
Based on Table 3, an efficient production process from July to November (year-end period). The quality of the raw materials used was quite good so the number of losses during the production process was low. In the year-end period, the production carried out by the five DMUs can be categorized as quite efficient because they can process inputs well to produce outputs. The SMEs “DMU4” and “DMU5”, show the average sales results that have achieved the target. High demand from retailers is one of the causes of fast-selling products and permeated by the market. High sale results are also shown by SMEs “DMU2”, but the number of losses generated in SMEs “DMU2” is still relatively high. This was triggered by the lack of supervision from the owner of SMEs “DMU2” that employees became less careful at work. Therefore, the producers who run the process efficiently can be used to reference other producers who experienced production inefficiency [18].

It needs sensitivity analysis to identify important constraints on input variables, simplify the model, and identify research priorities [19]. The sensitivity analysis results show the variables that have a significant effect on the efficiency value, so it is found which variables need to be prioritized in the improvement treatment. In this study, a sensitivity analysis was carried out followed by the preparation of improvement proposals. The improvement proposal is based on data processing results using Banxia Frontier Analysis software in the form of a potential improvement table. Through the potential improvement table, the actual value, the target value (the value that should be achieved), and the percentage of potential improvement will be discovered (the percentage of the actual increasing or decreasing value toward the target value). One of the sensitivity analysis results on SMEs “DMU1” can see from the value of potential improvement shown in Table 4.

The results of the sensitivity analysis of SMEs “DMU1” shows that the variables which have a major influence on the overall efficiency value are losses and selling prices. The main cause of losses usually occurred due to employees’ inappropriate work, causing some waste. Based on observation on the existing activities, some inappropriate works occurred by the employees such as improper frying process. The employees used the under-temperature oil when cooking the tempeh chips, making the tempeh chips too oily. The other is an over-temperature oil caused burning of tempeh chips.

Table 4. Value of potential improvement in production for SMEs “DMU1”.

| DMU | Month | Variable | Actual (IDR) | Target (IDR) | Potential Improvement (%) |
|-----|-------|----------|--------------|--------------|--------------------------|
| “A” | January | X1 | 5,460,000 | 5,231,142.91 | -4.2 |
|     |       | X2 | 5,304,000 | 5,050,681.69 | -4.8 |
|     |       | X3 | 573,000  | 548,982.58 | -4.2 |
|     |       | Y1 | 38,220,000 | 38,220,000 | 0.0 |
|     |       | Y2 | 6,000    | 6,000     | 0.0 |
|     |       | Y3 | 38,220,000 | 38,220,000 | 0.0 |
|     | April  | X1 | 4,550,000 | 4,351,818.80 | -4.4 |
|     |       | X2 | 4,420,000 | 4,196,481.12 | -5.1 |
|     |       | X3 | 467,500  | 447,137.43 | -4.4 |
|     |       | Y1 | 31,200,000 | 31,200,000 | 0.0 |
|     |       | Y2 | 6,000    | 6,000     | 0.0 |
|     |       | Y3 | 31,200,000 | 31,200,000 | 0.0 |
|     | July   | X1 | 4,550,000 | 4,468,812.69 | -1.8 |
|     |       | X2 | 4,420,000 | 4,338,609.21 | -1.8 |
|     |       | X3 | 450,500  | 442,461.56 | -1.8 |
|     |       | Y1 | 31,200,000 | 31,200,000 | 0.0 |
|     |       | Y2 | 6,000    | 6,000     | 0.0 |
|     |       | Y3 | 31,200,000 | 31,200,000 | 0.0 |
The under-temperature or over-temperature was observed by visual of the oil (expert worker experience), the air temperature above the frying oil (expert worker experience), and the frying test used some tempeh samples. The oily and burnt tempeh chips are under the quality standard and cannot be sold. In the work process, the company needs to control and direct the workforce to avoid obstacles in the production process. Control efforts are mentioned reducing losses during the production process, namely, increasing the frequency and shortening the supervision time interval during the production process to prevent employee negligence [20]. Supervision during the work process is carried out to cognize the performance taken to reduce errors and cost losses. This has a major impact on the number of losses occurred [21]. Besides reducing the number of losses, the supervision of the owner of SMEs "DMU1" aims to improve the quality of employee performance and increase the potential benefits obtained.

The results of the data analysis of improvements that need to be made on SMEs "DMU1" can be seen in Table 4, namely the variables of raw materials (X1), labor (X2), and losses (X3) that have an impact on production results (Y1), selling prices (Y2) and sales results (Y3). The highest potential improvement value for losses of 5.3% occurred in October. In the raw materials (X1) and labor (X2) variables, the highest potential improvement values were also found in December of 21.8%. Business owners need to improve the use of these two resources so that expenses can be managed efficiently. The field conditions in the month showed an excess of the number of raw materials and labor used. Thus, determining the right amount of raw materials and labor reduces expenses. One of the actions that business owners can take is to plan well in allocating the costs of raw materials and labor. The business actors are expected adjusting the amount of use of the two resources according to the needs and conditions of the production capacity.
Planning is a strategy to achieve organizational goals and improve that they are clearer and more structured. Consequently, it can reduce the risk of unwanted things happening [22]. The other actions are expanding market networks, increasing the sales volume, and increasing the tempeh chips’ competitiveness. Innovative marketing can be used to increase sales volume. The marketing innovations applied in an enterprise can increase the competitiveness of the product. Innovative marketing has been improving competitiveness by boosting sales volume and reducing costs [23]. Evaluating and upgrading supply management is good for expanding the market networks. A responsive supply chain management will respond to the market changes effectively and efficiently [24]. From a marketing perspective, effective supply chain management increases the market share and sales. It creates a solid relationship with the customer [25], thus are good strategies that will expand the market network. Increasing or maintaining competitiveness can be done by focusing on improving supply chain management [26].

The other important strategy that SMEs must do is increasing the product competitiveness of tempeh chips by improving packaging design, the taste of tempeh chips, and service quality based on consumer needs. An innovation product is referred to the release and development of goods or services based on the market demands or customer needs that lead to superior performance. High market knowledge will increase the competitiveness of the product and make easy new product development. The competitiveness of a product is one of the factors that affect the competitive advantage. High marketing performance can be achieved by the competitive advantage of the company [27].

4. Conclusions
The research result shows that variables affecting the efficiency of tempeh chips production are losses, labor, and sales. These three variables have a significant effect on the efficiency value of each DMU. The efficiency value of the five tempeh chip industries, with 6 months of production time on average ran inefficiently. The overall efficiency value is 89.4%–100%. The efficiency conditions are classified into three conditions, namely red, amber, and green. The high number of losses caused the inefficient production process, poor use of resources, and limited marketing reach which caused low sales volume. The proposed improvements for the inefficient production process can be carried out by considering the target value in the potential improvement result. Furthermore, some suggestions for improvement are; improving raw material planning and employee performance to reduce the number of losses that occurred; expanding market networks, as well as creating innovative marketing strategies to increase sales volume, evaluating and upgrading the supply chain management for expanding market networks, increasing the sales volume by optimizing social media marketing, and increase the tempeh chips products competitiveness such as improving packaging design, the taste of tempeh chips, service quality as well as improving products based on consumer needs.

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