Green productivity analysis of tempeh chips production

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Abstract. Tempe chips is one of the specialities foods of Malang City. An increase in number of domestic tourists in a particular region has contributed in increasing the demand of this kind of specialities food. The purposes of this research were to measure the productivity value, determine several improvement strategic alternatives, and estimate the influence of selected alternative to a better productivity. A suitable approach to help the SMEs to increase productivity and reduce environmental impact is the Green Productivity Method. Green Value Stream Mapping (GVSM) was also used to identify green waste. Green Productivity Index (GPI) of current tempeh chips production was only 0.28 (low). Alternatives were prepared to overcome several green waste problems. The results of the study showed that the most significant waste (sequentially) came from the frying process (emission), seasoning making process (wastewater), and packaging process (solid waste). There were three improvement alternatives to increase productivity values, namely: standardisation of packaging weight into 100 g/package, a blower usage only during frying process, and measurement of water consumption in seasoning process. Selection of best improvement alternative is done by using pairwise comparison method. The findings also confirmed that the alternative with the highest GPI were standardisation of packaging weight (0.30). The application of green productivity might be implemented because it could improve the economic value to be 2.48, and environmental impact (GPI future) to be 0.30 and GPI ratio to be 1.08. Future studies could measure productivity with other methods such as Benefit Cost Ratio (BCR).

1. Introduction

An increase in the number of domestic tourists in a particular region has contributed in increasing the demand of local food and souvenirs. This increase in visitors has triggered the domestic tourism industry to expand. In Malang City, for instance, data from Central Bureau of Statistics [1] has reported that the number of local tourists has significantly increased from 158,343 to 281,394 visitors. Such conditions have positive impact on local economy development as shown by many souvenir shops are selling Malang’s specialities foods, such as tempeh chips. Tempe chips was famously and locally produced from Sanan industrial center. The production process of tempeh chip consists of several stages and it is classified as labour intensive industry.

The increasing number of tourists also require high productivity of specialities food, especially tempeh chips. Productivity could be measured by comparing production output and input [2]. The low productivity raises more problems, for example from the disposal of material and energy during the production process that threatens the safety and health of the environmental. The strategy of productivity improvement is applied to increase output by reducing or saving input. The production output consists of tempeh chips, solid waste, wastewater, and emissions. Green productivity (GP) is a strategy to escalate the productivity of the company and environmental performance concurrently in socio-economic development [3]. The application of GP to SMEs is considered relevant because it begins with a strategy to improve productivity and environmental performance by analysing inputs, processes, and outputs [4]. It means that GP is an appropriate approach to help the company to increase productivity while reducing...
environmental impacts. The concept of productivity refers to aspects of environmental protection. The reduction of pollutants causes reduced solid waste, air emissions, and noise [5].

The green productivity determines the impact of production process on the environment by identifying each stage. It is done by using green value stream mapping (GVSM). The mapping will outline some problems that require the best alternative that concern to green productivity. Selection of improvement alternatives can be done by using a pairwise comparison method. The purpose of this study was to analyse productivity value by using the green productivity method to get several alternatives that can improve economic indicators and environmental impacts. This study also aimed to estimate the influence of selected alternative to a better productivity.

2. Research Method
This research was conducted at one of SMEs that produce tempeh chips in Malang, East Java, on March-April 2017. The data processing was done at Agro-industrial Management Laboratory, Department of Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia. Respondents for this research were two experts. They were the owner of tempeh chips SME and one of employee that has been working for more than four years. This research focused on the production of original tempeh chips in one batch. There were four main stages in tempeh chips production, namely cutting tempeh, seasoning, frying, and packaging. The types of waste analysed in this study were emissions, wastewater, and solid waste. Emissions came from calculated energy from Liquefied Petroleum Gas (LPG) and electricity consumption. The followings were the steps of data processing:
1. Calculating mass balance and productivity measurement
2. Calculating current GVSM
   In GVSM there are two stages, namely current-state and future-state. In this phase, three of the seven wastes produced in the tempeh chips SME were identified. The GVSM current-state was to describe the current waste identification mapping. The mapping was carried out by analysing the mass balance of each production stage [6]. The frying process used the electric blower for about 9 hours a day and the process of seasoning used an electric blender, while the LPG was used for fuel when frying. The formula for converting energy to emissions for LPG and electricity was:
   a. Electrical Energy
   \[
   CO_2 \text{ ton} = \frac{\text{amount of electricity usage (kwh) x Conversion factor (kg/kwh)}}{1000} \tag{1}
   \]
   Where:
   Electrical factor = 0.891 kg/kWh
   b. LPG (Gas Emission)
   \[
   \text{LPG} = F_{cy} \times EF \times \text{CO}_2 \times \text{NC/LPG} \tag{2}
   \]
   Where:
   \(F_{cy}\) = energy consumption
   \(EF \times \text{CO}_2\) = Emissions energy (kg/Terra Joule)
   \(\text{NC/LPG}\) = Heat value (Terra Joule/kg)
   Source : Ministry of Environment [7]
3. Calculating GPI
The calculation of Green Productivity Index (GPI) was carried out to determine the productivity ratio regarding to its environmental consequences. The green productivity index (GPI) was defined as the ratio of economic indicators to environmental impacts [8]. Economic indicators and environmental impacts were used in calculating productivity level. The general equation for the formula of GPI was:
\[
\text{GPI} = \frac{\text{Economic Indicator}}{\text{Environmental impact}} \tag{3}
\]
   a. Economic indicators
   Economic indicators were the ratio between the selling price and the production cost needed to produce one unit of product in the same unit type. The tempeh chips SME still derived standard equipment, so that the production costs came from the cost of raw materials, the purchase of equipment, employees, and other non-fixed costs. Calculation of economic indicator adopted the following formula:
3

b. Environmental impacts

Environmental impact was the magnitude of the waste impact generated from the production process in the environment. The value of Environmental Impact (EI) depended on the accumulation of three types of environmental indicators, each of which was obtained by multiplying the weight according to the expert at Environmental Sustainable Index (ESI) in 2005 [9] with the amount of waste produced from the production process. Environmental impact was defined as the sum of three weighting environmental variables, they are:

1. Gaseous wastes generation (GWG), with the indicators of air quality, greenhouse gas effects, and decreased in the levels of air pollution. This waste came from energy use, such as LPG and electricity for blender and blower.
2. Solid wastes generation (SWG) had an indicator of decreasing the amount of solid waste and material consumption. This waste came from the remaining plastic of tempeh wrap and stickers for packaging.
3. Water consumption had an indicator of decreasing water quality and amount of water. This waste came from sanitation when seasoning and frying, as well as the remaining seasoning pasta that stuck in the basin.

The use of the ESI indicator weight as a basis for weighting environmental impacts (EI) in this study, refers to the research conducted by Widhiarti et al [5]. The weight of environmental indicators on ESI can be seen in Table 1. The environmental impacts obtained are written in the formula:

\[
\text{Environmental Impact} = a_{GWG} + b_{WC} + c_{SWG}
\]

Where:
- GWG = gaseous wastes generation (ton)
- SWG = solid waste generation (ton)
- WC = water consumption (ton)
- a, b, c = weight of each GPI indicators (according to Table 1)

| Equality of Indicators ESI | Weight in ESI |
|---------------------------|---------------|
| Air quality               | 0.05          |
| The effect of greenhouse gases | 0.05        |
| Decrease air pollution level | 0.05          |
| Water quality             | 0.05          |
| Amount of water           | 0.05          |
| Decreasing the amount of solid waste and material consumption | 0.05 |

Source: Environmental Satisfaction Index [9]

4. Pairwise comparison

An improvement alternative was specifically applied to reduce a type of waste. So that alternative selection should be done using pairwise comparison. Comparing two strategies was made by using a preference scale, which gave numerical values to various preference levels. The standard preference scale used for AHP was 1-9 scale between "equal interests" and "extreme interests" [10]. Two experts compared the strategies by filling out the questionnaire based on the ease of implementation and probability the increasing of tempeh chip SME productivity in the nearest future. There was a consistency ratio (CR) of expert opinion, it showed the level of respondents’ expertise. Stages of calculations were [11]:

1. Multiplying the rows of each matrix
2. The value of the eigen vector was the geometric average of the elements of each row’s matrix
3. Calculation of Vector Priority (VP)
4. The more the CI value approaches 0, the more consistent the observation
5. The value of the consistency ratio (CR) should be smaller or equal to 0.1 (10%), it meant that it had good consistency.
5. Alternative evaluation
Evaluation of alternatives was done by depicting GVSM future-state and continuing with the calculation of GPI. Comparison of future and current values would be used to determine the GPI ratio produced by each alternative. The chosen alternative under the assessment of the two experts would be tested for its feasibility, by calculating the comparison value of the GPI future and current, resulting in a GPI ratio. If the GPI ratio is greater than 1, it means the chosen alternative increase in productivity is better than the initial GPI condition before improvement [12].

3. Results and Discussion
3.1. Mass balance
The first stage when making tempeh chips was cutting tempeh for several production cycles. One production cycle (one batch) had a capacity of three oval tempeh pieces, whereas the plastic waste covering oval tempeh was classified in the solid waste category. The tempeh crumbs classified as material and could be reprocessed into "Mendol" (Malang traditional food made from raw tempeh) or re-fried. The process of tempeh chips continued with seasoning as an outer coating of tempeh. Layers of seasoning on sliced tempeh would give a crunchy and savoury flavor. The seasoning stage produced wastewater by 0.075 L used for washing hands after the seasoning process.

The next stage was frying, included preparation of energy used for frying about 3 kg of LPG and preparation for sanitation in the form of hand washing water about 1.6 L. This process used a steady flame by two gas stoves and two pans. The remaining oil scraping the tempeh chips would be reused and reused to prevent the waste. The oil would absorb into tempeh, which had been wrapped in seasoning and fried. The outputs of this process were: tempeh chips by 38.003 kg, tempeh chip crumbs by 2.325 kg, as well as the remaining seasoning pasta that stuck in the basin by 4 kg. Tempeh chip crumbs in frying were categorized as material and could be used as an additional fuel in boiling soybeans for the supplier of tempeh. The primary packaging of tempeh chips used polypropylene plastic with a thickness of 0.10 mm and weighed of 0.005 kg. According to Wulandari [13], polypropylene was a crystalline polymer produced from the polymerization process of propylene gas, which had a high melting point (190°-200°C), while the crystallization point was between 130°-135°C. In the packaging stage, waste generated included damaged packaging materials about 0.147 kg and tempeh chip crumbs about 3.107 kg. The tempeh chips crumbs in packaging stage were usually sold to the customers cheaply, the price was about IDR 7,000/kg.

3.2. Green value stream mapping current (GVSM)
There were several waste sources in the processing of tempeh chips, namely: water, material, and energy, so that it generated green waste: water consumption, solid waste, and emissions [14]. The results of the green waste analysis in tempeh chips production are shown in Table 2. Wastewater calculated was based on the amount of water used during the production process. The amount of wastewater came from the mixing in the seasoning process, wastewater to wash hands in the frying process, and remaining seasoning pasta that stuck in the basin. The used energy in the seasoning process was electricity to operate the blender, while in the frying process, energy used came from the emission of LPG and electricity of blower. Green waste of material was not considered in environmental indicators because it could be reused and resold.

| Type of Waste       | Production Process (in one batch) | Total    |
|---------------------|-----------------------------------|----------|
|                     | Cutting  | Seasoning | Frying | Packaging |          |
| Energy (Kwh)        | -        | 0.03750   | 1.35000| -         | 1.38750  |
| Water Consumption (ton) | -        | 0.01060   | 0.00560| -         | 0.01620  |
| Solid Waste (ton)   | 0.00003  | -         | -      | 0.00015   | 0.00018  |
| Material (ton)      | 0.00049  | -         | 0.00232| 0.00311   | 0.00592  |
| Emission (ton CO₂/day) | -        | 0.00003   | 0.00560| -         | 0.00563  |
3.3. Value of GPI

According to Marimin [15], the concept of GPI calculation could use several types of data retrieval, namely: at one hour during the production process, at one production cycle (one batch), and one day during the production process. In this study, the GPI calculations were carried out in one cycle of making tempeh chips (one batch).

3.3.1. Economic indicators

Financial calculations and the average production capacity of SMEs were 16 pieces or around 72 kg. This study focused on product with had 100 g/packaging weight at one batch, which was three pieces (339 packs) with a selling price of IDR 3,500.00. The value of the economic indicator was 2.29, it meant good, the value > 1 means the sale had been profitable. According to Marimin [14], the calculation of economic indicators was calculated from a comparison between the sales revenue and the total production cost. Based on green productivity principles, the productivity calculation does not only consider about financial profits, but also the environmental impacts.

3.3.2. Environmental indicators

The calculation of each indicator in environmental impact was gained from the sum of each value of gaseous waste (emission), liquid (wastewater), and solid (plastic packaging). According to Gandhi et al (2006), environmental indicators are the sum of gaseous waste, wastewater, and solid waste [16]. Calculation of the environmental impact generated during the process of making tempeh chips is carried out using formula (5). The environmental indicator was 8.24. Environment impact (EI) depended on the multiplication between the sum of the green productivity indicator weight equations, with the amount of waste for each type of indicator. The greater the value of the environment impact, so the higher the value for the environment given from a process [17].

The GPI value obtained was 0.28 in which the value of environmental impacts (environmental indicators) was higher than the economic indicators. According to Fitri [2], the higher value of the GPI was achieved, so the higher level of productivity and economic indicators would also achieved. On the other hand, the environmental impact of the production process would be the lower. Therefore, several alternatives were needed to increase the GPI value.

3.4. Alternative selection

The expert suggested some alternatives that could increase the GPI value in the production process [15]. It was designed to increase economic indicator values or reduce environmental impacts (reduce green waste). Economic indicator values would affect production costs and selling values. Reducing green waste focused on two variables, namely wastewater and emissions because both of these had the highest value compared to solid waste. There were three alternative strategies for increasing GPI values, they were:

1. Standardisation of packaging weight into 100 g/package (X1)
2. A blower usage only during the frying process (X2)
3. Measurement of water consumption in seasoning process (X3)

The selection of these alternatives was considered because they were most likely to be applied in production process in the nearest period.

3.4.1. Calculations of the selected alternative

The results of alternative weights could be seen in Table 3. This research found that the alternative solution with the highest ranking was standardization of packaging weight into 100 g/package (X1). Standardization of weight per package could be carried out by weighing each packaging after finishing putting tempeh chips to the packaging plastic.

| Alternatives | Weight value | Ranking |
|--------------|--------------|---------|
| X1           | 0.48         | 1       |
| X2           | 0.27         | 2       |
| X3           | 0.24         | 3       |
3.5. Increased value of selected GPI alternatives

Increasing the value of GPI could come from the rising value of economic indicators and reducing environmental impacts. Two alternatives (standardization of packaging weight into 100 g/package and measurement of water consumption in seasoning process) had their respective contributions towards inclining the value of economic indicators. For another alternatives, a blower usage only during the frying process and also measurement of water consumption in seasoning process, could reduce environmental impacts. A comparison of economic indicator values and environmental impacts for current and future is in Table 4.

| Alternatives | Economic Indicator current | Economic Indicator future | Environmental Impacts current | Environmental Impacts future |
|--------------|---------------------------|---------------------------|------------------------------|------------------------------|
| X1           | 2.30                      | 2.49                      | 8.24                         | 8.24                         |
| X2           | 2.30                      | 2.35                      | 8.24                         | 8.00                         |
| X3           | 2.30                      | 2.35                      | 8.24                         | 8.22                         |

Table 4 shows the effect of improvement alternative implementation. There are increasing value for economic indicators and decreasing value for environmental impact for each alternative. The calculation of the GPI ratio was carried out by comparing the future and current values. The chosen alternative was the alternative with the highest GPI ratio, namely the standardization of the packaging weight into 100 g/package. This alternative had a significant increase in economic indicators value, which also potentially to significantly improve its GPI future and the GPI ratio. The value of the GPI ratio for each alternative can be seen in Table 5.

Table 5. The value of GPI ratio for each alternative productivity

| Alternative | GPI current | GPI future | GPI ratio |
|-------------|-------------|------------|-----------|
| X1          | 0.28        | 0.30       | 1.08      |
| X2          | 0.28        | 0.29       | 1.05      |
| X3          | 0.28        | 0.28       | 1.02      |

The actual weight when packaging had no standard and overweighting was often happened. It was because the employee did not weigh each package during packaging process. If the alternative applied, additional of 27 packages are potentially to be produced in each production process. Indeed, this may have an impact on increasing the selling price (profit). Increased value of the GPI ratio for alternative chosen was 1.08, much higher than that of other alternatives. Therefore, the chosen alternative can be implemented in the nearest future as it requests a small change of the packaging method. According to Marizka et al. [12], the GPI ratio was developed in making decisions to choose one of the best alternatives in improving green productivity performance of the existing system.

3.6 GVSM future

The mapping of the GVSM future was the final stage of the description of the selected alternative improvements. The chosen alternative was the first alternative (X1), namely standardisation of the packaging weight into 100 g/package. In this GVSM future, there was a change in the packaging process, resulted an increase of 170 g solid waste (i.e. plastic and stickers). This addition was due to additional packaging was required for 27 packages of tempeh chips. However, this addition has no impact on the environmental impact as shown by EI values. The experts selected the alternatives based on two considerations, include the implementation of alternative in the nearest future and the benefits. The advantage gained by SME owners was an increase in productivity. It also could increase the wages of packaging employees as it depended on how many packages of tempeh chips were produced in a day.
4. Conclusions

The GPI value in the SMEs tempeh chips was low (0.28). Three improvement alternatives were suggested, namely: standardisation of packaging weight into 100 g/package, a blower usage only during frying process, and measurement of water consumption in seasoning process. The chosen alternative to improve the GPI was standardisation of packaging weight into 100 g/package. This alternative can increase in the GPI future value to 0.30 and a GPI ratio to 1.08. The application of green productivity may be implemented in SMEs from the beginning of production process because it can improve the economy and environmental impact. For the future research, productivity can be measured with other methods such as Benefit Cost Ratio (BCR) or Net Present Value (NPV).

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