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Green productivity analysis at tofu production (case study of UD Gudange Tahu Takwa Kediri)

R Septifani, P Deoranto and I Jannah

Department of Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

Email: riskaseptifani@ub.ac.id

Abstract. UD. Gudang Tahu Takwa (GTT) is one of tofu Small and Medium Enterprises (SMEs). In Kediri, there are many tofu SMEs, each of them competes to survive in the market by improving and increasing productivity. The purposes of this study were to determine the most influenced factors towards productivity level and to determine the best wastewater treatment alternatives to be applied. An approach to improve productivity while lowering environmental impacts is known as Green Productivity (GP). The GP approach can be applied by using several tools such as mass balance, causal diagram, Environmental Performance Indicator (EPI), and Net Present Value (NPV). The results show the lowest productivity was washing process with the value of 17%. The EPI index total was -3.94 indicating that the environmental performance was still under the quality standard. The findings further suggested two alternatives to be implemented to improve productivity level, include replacement of suppliers and procurement of filtration equipment. The most influenced factor on productivity level was the volume of wastewater generated. Therefore, the second alternative was selected, due to its implementation could increase the productivity level of washing process by 79%, increase the EPI index to -3.00 and reduce the NPV value to IDR 1,582,204. The suggestion from this research is that UD GTT should buy the filtering equipment, and then applied it to treating the wastewater.

1. Introduction
Tofu is a typical Kediri food made from soybeans and it is very much sought after by people as a typical Kediri hand gifts. Therefore, the surrounding community takes an advantage of it by opening business opportunities. The data from the Industry and Trade Department (Disperindag) Kediri shows that there are 149 units of small and medium enterprises (SMEs) of Takwa tofu [1]. The large numbers of these SMEs have motivated the owners to continue their survival in the market competition by increasing the productivity level. Productivity is the ratio between the results achieved (output) and the overall resources used (input) [2]. Increased productivity is crucial in every production process, improving both the output quality and the efficiency of resources. Increasing the production of tofu can cause environmental problems to its surrounding environment because of the disposal of materials and energy that burden the environment.

UD. Gudange Tahu Takwa (GTT), established in 1990, is one of tofu SMEs. UD. GTT is located at Toyoresmi Village Ngasem District of Kediri Regency. This SME sells a variety of processed tofu such as takwa tofu, round tofu, tofu stick, tofu chips, tofu crackers, crispy tofu, emping tofu, and
Sumedang fried tofu. Its main product is *takwa* tofu, with a production capacity of 250 kg per day. During the production process in UD. GTT, both solid waste and wastewater were generated. The solid waste produced is further processed as cattle feeds. However, wastewater was directly disposed without any treatments, thus contributing to damaging the surrounding environment and the neighbourhood community. The wastewater is generated from washing, soaking, and tofu pressing process. The problems of waste in UD. GTT required further measures, for instance by applying waste management in the production process, which is expected to positively affect the productivity of the company.

One of the approaches to improve productivity while lowering environmental impacts is the Green Productivity (GP) method. The GP is a strategy to increase corporate productivity and environmental performance simultaneously in socio-economic development as a whole. The application of GP to SMEs is considered relevant because it begins with a strategy to improve productivity and environmental performance by analyzing inputs, processes, and outputs. The GP shows the way to reduce the practical impact on the environment that can lead to cost savings and risk reduction. The GP also produces significant benefits for increased productivity [3].

Productivity measurement is carried out by using the result of mass balance calculation in each production process. The GP approach can be applied by using several tools such as cause and effect diagram and Net Present Value (NPV). Factors that affect the level of productivity can be identified using a cause and effect diagram. Cause-and-effect diagrams are simple graphical methods to hypothesise the cause and effect chain [4]. The determination of the best improvement alternative in handling waste and increasing productivity use NPV. The NPV is a tool that compares the costs and benefits of some alternatives [5]. The purpose of this research is to determine the factors that most influence the level of productivity of tofu production process and the best alternative for waste treatment to improve the environmental performance at UD. GTT.

2. Materials and Methods
2.1. Materials and instruments
This research was conducted at UD. GTT from March to April 2017. The data processing is carried out at the Computational and System Analysis Laboratory, Department of Industrial Technology of Agriculture, Faculty of Agricultural Technology, Universitas Brawijaya, Malang. Instruments used in this research were mass balance, Environmental Performance Indicator (EPI), Fishbone diagram and NPV.

2.2 Method
The followings are the steps of data processing [6]:
1. Calculating mass balance and measurement of productivity
2. Determining the EPI
   The measurement of EPI Index is useful to minimize waste generated in the production process and increase its productivity [6]. If the positive EPI value indicates the company's environmental performance is good. Conversely, if the value of EPI is negative, then the company's environmental performance is not good [5]. The measurement of the EPI index can be formulated as follows:

   \[
   \text{Index EPI} = \sum_{i=1}^{k} W_i \cdot P_i
   \]

   (Where, \( k \) = number of waste criteria proposed, \( W_i \) = weight of each criterion, \( P_i \) = deviation from each criterion between normal waste standard and laboratory analysis result)

   The EPI shows the environmental performance shown by analyzing the results of the search waste test from UD. GTT and wastewater quality standards. The parameters used are biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and pH. Those four parameters were used to determine the level of wastewater pollution in UD. GTT.
The weight value is obtained from the results of the questionnaire filled by two experts and processed using pairwise comparison
3. Identifying the cause of the problem by using a Fishbone diagram
4. Selecting the best alternative solutions by using NPV

3. Results and Discussion
3.1. Results of mass balance and productivity calculation
The calculation of mass balance requires input and output in each production process. Inputs used are soybeans, water and vinegar, while the resulting output is tofu and waste. Waste generated is in the form of wastewater and solid waste (tofu dregs). The process that distinguishes takwa tofu and the ordinary tofu is in the process of coloring by adding turmeric. Coloring is carried out by boiling the tofu that has previously been moulded on a wood stove. Productivity calculation is obtained from the comparison between output and input in each production process. The steps of tofu production are washing, soaking, draining, milling, boiling, filtering, forming, and coloring. The highest level of productivity was found on the soaking process with the value of 100%. This is because soy soaking does not produce waste. Residual water soaking discharged in the draining process. The lowest productivity level was in the washing process counted for 17%, due to a high water usage. A large amount of water is used because the soybean contains too much dirt. Compared to all production processes, the washing process is the only process having the productivity level below 50%. Productivity level that falls into the high category should be above 50% [7].

3.2. The measurement of EPI
Table 1 shows that the EPI index on COD and TSS parameters show a negative value, then the EPI index value in COD is also negative (-3.85). A negative EPI index value means that the productivity performance on the environment is not good. The laboratory results showed that the COD concentration exceeded the standard effluent quality, possibly due to the addition of vinegar in the filtering process. Similarly, the TSS concentration also exceeded the standard values. The result shows that the deviation value obtained was -2.60, thus the value of the EPI index on TSS is also negative (-0.49). The high value of TSS is possibly due to the use of soybeans that contain lots of epidermis, and twigs or gravel. The total value of EPI index was also negative with value of -3.94, meaning the environmental performance of UD. GTT is still below the quality standard and the environmental pollution is still high. The quality of wastewater generated from UD. GTT did not meet the environmental quality standards. The EPI index is necessary because it reflects the impacts of an environmental activity and its reducing efforts [8]. The high value of COD causes the absence of aquatic biota and disturb the balance of aquatic ecosystems, while the high level of TSS will reduce the depth of sunlight penetration into the water and it also reduces the value of water and affects the organisms living in it [9].

| Parameter | Weight (Wi) (a) | Standard Quality of Raw Liquid Waste (b) | Result of Lab Analysis (c) | Retention (Pi) (%) (d) = ((b-c)/b)*100% | EPI Index (e) = a*d |
|-----------|----------------|------------------------------------------|---------------------------|----------------------------------------|-------------------------|
| BOD       | 0.34           | 50.00                                    | 1.36                      | 0.97                                   | 0.33                    |
| COD       | 0.22           | 100.00                                   | 1,851.60                  | -17.52                                 | -3.85                   |
| TSS       | 0.19           | 200.00                                   | 720.00                    | -2.60                                  | -0.49                   |
| pH        | 0.25           | 6.00                                     | 4.04                      | 0.33                                   | 0.08                    |
|           | | | Total of EPI Index | | -3.94 |

Table 1. Result of calculation of EPI index.
3.3. Identify problems and causes
In the previous discussion, it was found that the washing productivity level is still low and the COD and TSS values still exceeded the standard. Therefore, the Fishbone diagrams were used to identify each problem. It was found that there is no standard for the soybean, whether it is clean or not. UD. GTT has not prepared any quality standards of soybean so that it depends on the expertise of the employees. Therefore, to overcome this problem, the standard quality of soybean should be made. It was also found that the used soybeans still contain dirt, causing a large amount of water needed in the washing process. Another cause is due to the use of conventional machine which is manually operated using a regular tub. This manual method requires a lot of water in the washing process. The high amount of water consumption is equal to the resulted wastewater [10]. Another cause is the addition of a high concentration of vinegar, which can cause undesirable odor. Such condition may lead to the excessive amounts of chemicals in the wastewater. High COD concentration will be followed by an increased need for oxygen to break down organic matter. The tofu wastewater that continuously discharged without treatment into the river will affect its water quality [11].

3.4. Compilation of alternatives and repair solutions

a. Alternative 1
Alternative 1 was carried out by choosing the suppliers with good soybean seed. The characteristics of good soybean seeds include the soybeans should be clean, having large seeds and free of epidermis, gravel, twigs. Soybean with such characteristics can be obtained from Jalan Raya Mojo Mlati Village, Mojo Subdistrict, Kediri regency. The price of the soybean was IDR 7,500.

b. Alternative 2
Alternative 2 was carried out by procurement of filtration equipment and filter basin. This filtration equipment is made in a tube with a diameter of 100 cm and a height of 150 cm. The main ingredients in this filtration tool are water hyacinth and banana peel [11]. Water Hyacinth can absorb nutrients, organic compounds and chemical elements, while banana peels can bind heavy metals and liquid waste. Other additives are gravel, sand, charcoal and woven cotton. Each material is sequently arranged inside the tube, while the filter basin is built with a volume of 600 L. The filter materials of this filtration equipment must be replaced each day to avoid any clogging or blocking. Tofu wastewater is left in a reservoir pool for 12 hours (in a cold condition), functioned as a sedimentation tank to reduce the concentration of dissolved solids. Then it is flown into the pipe, and into the filtration tube. The absorption capacity of this filtration device is 1 liter per 2 minutes [11].

The water hyacinth can be utilised as an absorbent material due to its ability to absorb toxic substances in the environment. The advantages of water hyacinth are reducing pollutants, purifying wastewater by biofiltration, absorbing heavy metals such as Pb, Cd, Hg, Zn, Fe, Mn, Ni, Au, Co and Sr, absorbing organic compounds and other contents [12]. Also, the utilisation of banana peels as an absorbent material can increase their economic value. Banana peels contain nitrogen, sulfur and organic compounds such as carboxylic acids [9]. Banana peel that has been dried and cut is useful to bind to the compound of the mixture contained in the wastewater. Charcoal is wood that has been carbonized with partial combustion with little air. Charcoal is useful for cleansing water because it releases chlorine and other harmful substances. Charcoal is wrapped in cloth so that there is no powder scattered everywhere. Charcoal should be sterilized in boiling water first, then dried under the sun before used. Sand is useful for filtering dissolved solids (size of 0.2 to 0.8 mm), while gravel works for final filters before wastewater is disposed into the river.

3.5. Financial analysis of any alternative using the NPV
The selected alternatives are expected to overcome the environmental problems faced by UD. GTT. Financial feasibility analysis combined with NPV was used to select the best alternative.
Table 2. NPV alternative 1.

| Interest rate (12%) (a) | Total Saving (IDR) (b) | Invest (IDR) (c) | Operational and Maintenance (IDR) (d) | PV Benefit (IDR) (e)=(b*a) | PV Cost (IDR) (f)=c+(d*a) | NPV (IDR) (g) = (e-f) |
|------------------------|------------------------|------------------|--------------------------------------|-----------------------------|-----------------------------|------------------------|
| 0.89                   | 51,261,224.88          | 43,800,000       | 0                                    | 45,771,148                  | 43,800,000                  | 1,971,148              |

Table 3. NPV alternative 2.

| Interest Rate (12%) (a) | Total Saving (IDR) (b) | Invest (IDR) (c) | Operational and Maintenance (IDR) (d) | PV Benefit (IDR) (e)=(b*a) | PV Cost (IDR) (f)=c+(d*a) | NPV (IDR) (g) = (e-f) |
|------------------------|------------------------|------------------|--------------------------------------|-----------------------------|-----------------------------|------------------------|
| 0.89                   | 13,277,506.36          | 4,785,000        | 5,872,590                           | 11,810,840                  | 10,028,636                  | 1,582,204              |

3.6. Alternative selection

After determining the NPV value, the amount of waste, the productivity, and the EPI index in each alternative, next step is choosing the best alternative. This study shows that the chosen alternative was alternative 2, which may increase the productivity level to 79% and the EPI index of -3.00. In terms of the NPV value, however, the alternative 1 is more beneficial (IDR 1,971,148) compared to that of the alternative 2 (IDR 1,582,204). The alternative 2 was chosen because it has a better productivity level and the EPI index than alternative 1. The GP has several objectives in order to improve the environmental quality and production of waste reduction, material management, pollution prevention and product enhancement [13].

Table 4. Comparison of alternative result 1 and alternative 2.

| Alternatives   | NPV (IDR) | Amount of Waste | Productivity (%) | EPI Index |
|----------------|-----------|-----------------|------------------|-----------|
|                | Before (L) | After (L) | Percentage (%) | Before | After | Before | After |
| Alternative 1  | 1,971,148 | 58.94 | 30.14 | 48.46 | 17 | 29 | -3.94 | -3.25 |
| Alternative 2  | 1,582,204 | 58.94 | 17.59 | 75.00 | 17 | 79 | -3.94 | -3.00 |

4. Conclusion

The findings confirmed that the productivity level in UD. GTT was mainly caused by the amount of wastewater generated from the production process. Specifically, the washing process has poor environmental performance as indicated by its lowest productivity level, measured at 17%. This was due to a high amount of water used to wash the soybeans. To tackle this problem, it was suggested that UD. GTT to apply alternative 2 (i.e. the procurement of filtration equipment). Despite a high NPV value, by selecting this strategy, UD. GTT might experience an increase in the productivity level to 79% and in the EPI index to -3.00. This study further demonstrated that the GP approach is an applicable tool to help SMEs in the decision-making process aiming at improving their environmental performance.

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