Green Productivity Analysis in Tofu Industry (Case Study: Pak Sadino Tofu Industry on Selili Village)

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Abstract. "Kampung Tahu Selili" is one of the tofu industry areas located in Samarinda City. The production process still uses traditional methods, resulting in waste being directly discharged into the river. This study focuses on the Pak Sadino Tofu Industry, one of the tofu industries in Selili. The aim of this research is to identify the highest waste output and find solutions to reduce it. This research used Green Productivity method which consists of mass balance measurement, Green Value Stream Mapping (GVSM), calculation of Environmental Impact (EI) and Green Productivity Index (GPI), Green productivity option, and proposing alternative solutions. The results show that a GPI value of 0.785, indicating a still low green productivity level, with the most waste found in the sedimentation process amounting to 1,523 kg. The selected alternative solution, based on the element importance scale calculation, is the production of organic fertilizer, which has the highest weight among the three alternatives, namely 0.38. This solution is expected to improve environmental performance and productivity value.

Keywords: Enviromental Impact, GPI, Green productivity, GVSM, Waste

1 Introduction

With a population of 3.77 million, East Kalimantan has various types of goods and services businesses managed by Small and Medium Enterprises (SMEs). Samarinda City, the capital of East Kalimantan, has 1,693 SMEs, 279 of which are engaged in food processing. The tofu industry is one of the labor-intensive food processing businesses. Kampung Tahu Selili is one of the tofu production centers in Samarinda.

In the tofu industry, most production costs are allocated to purchasing the main raw material, soybeans. The average price for a 50 kg sack of soybeans is Rp. 500,000. From using 50 kg of soybeans, the average profit is Rp. 50,000 or 10%. Besides being profitable, the tofu processing business also has environmental impacts, generating significant waste, including solid waste (soybean skin, scraps, and tofu dregs) and liquid waste (soaking water, washing water, and tofu water). From using 50 kg of soybeans, the average solid waste produced is 10 kg and liquid waste is 5,000 liters.

According to Law No. 32 of 2009, which regulates waste and production residue levels, waste is defined as any residue or production result discarded, abandoned, or

disposed of by humans and/or natural processes containing hazardous materials. Government Regulation No. 22 of 2021 requires business actors to manage the waste that they produced.

The Pak Sadino tofu processing SME is located in the Kampung Selili tofu processing center, Samarinda City. The tofu processing stages in this business are as follows: washing, draining, measuring, grinding, boiling until it reaches a boil, filtering, adding vinegar, settling, molding, pressing, and cutting. The average daily raw material usage is 2,500 kg of soybeans, 27,500 liters of water, and 1 cubic meter of firewood. The average daily tofu production is 18,750 pieces, equivalent to 6,500 kg. In its production process, this industry generates 500 kg of solid waste and 250,000 liters of liquid waste daily. The waste is not processed; the solid waste is used as animal feed, while the liquid waste is directly discharged into the river.

According to Kaswinarni, the solid waste from tofu processing plants contains calories, protein, fat, carbohydrates, calcium, phosphorus, iron, vitamin B, and water, which causes it to spoil quickly (producing a foul odor). In contrast, liquid waste contains protein, nitrogen, suspended solids, and phosphorus, so the discharge of liquid waste into the aquatic environment can increase bacterial growth in the water [1]. This results in ecosystem disruption, environmental pollution, and ultimately affects business productivity.

To address productivity issues and minimize the environmental impact of the tofu industry, the green productivity method is used. According to the Asia Productivity Organization, Green Productivity is a strategy for simultaneously improving company productivity and environmental performance with a comprehensive socio-economic scope [2-4]. Green Productivity can also be described as eco-friendly productivity, part of a productivity improvement program amid global sustainable development issues. The Green Productivity method has advantages in helping improve productivity with environmentally friendly management, efficient costs, and reducing the risk of negative impacts. It is hoped that by conducting research with Green Productivity, productivity can be improved and the environmental impact of the Pak Sadino tofu industry in Kampung Selili can be minimized.

2   Methods

To achieve the objective of this study, quanlitative research methodology was used. The methodology was started by interviewing the owner regarding the main product and the process production, production cost, the amount of revenue, amount of production, and amount of waste. Next, After obtaining the necessary data, calculations can be carried out using several methods applied.

In this study, several methods are used, including mass balance preparation, productivity measurement, creation of Green Value Stream Mapping (GVSM), calculation of the Green Productivity Index (GPI), determination of the lowest productivity value, and creation of a Fishbone Diagram to identify the causes of low productivity in the processes found in the previous stages.

2.1   Mass Balance Preparation

The basic concept of a mass balance is that the amount of material entering a process unit is equal to the amount exiting the unit, in accordance with the law of mass conservation. This fundamental principle is applied when there is no accumulation in the processing equipment; in any system, the amount of material will remain constant even if there are changes in form or physical state. The mass balance in the production process of a factory can reveal waste that is not identified in the inputs (including losses). Mass balance calculations are performed for each component in addition to the total mass balance calculations for process streams that contain more than one component. The complete mass balance can be seen in Table 1.

Table 1. Mass balance

PROCESS	INPUT QUANTITY	OUTPUT QUANTITY	WASTE
Soaking	550	490	60
Washing	790	530	260
Griding	1450	1448	2
Cooking	3248	2856	392
Filtering	2856	2102	754
Sedimentation	2402	879	1523
Molding	879	797	82

2.2   Productivity Measurement

Productivity is defined as the relationship between input and output in a production system. All resources used to produce the output are referred to as input, while all the good production results are called output. The equation used for measuring productivity is as follows:

$$\text{productivity} = (\text{output produced/input used}) \times 100\% \tag{1}$$

The productivity calculation values can be seen in Table 2.

Table 2. Productivity Measurement

PROCESS	INPUT QUANTITY	OUTPUT QUANTITY	PRODUCTIVITY	WASTE (KG)
Soaking	550	490	89,09%	60
Washing	790	530	67,09%	260
Griding	1450	1448	99,86%	2
Cooking	3248	2856	87,93%	392
Filtering	2856	2102	73,60%	754
Sedimentation	2402	879	36,59%	1523
Molding	879	797	90,67%	82

2.3 GVSM

GVSM is a method that can determine the environmental impacts, such as energy consumption, process waste, raw material waste, water consumption, transportation, gas emissions, and biodiversity [4]. The measurement of green productivity is the ratio between economic indicators and environmental indicators. The calculation of environmental indicators is obtained, among other ways, from the analysis of the seven sources of waste generation through GVSM [5]. The determination of GVSM can be seen in Table 3.

Table 3. GVSM

PROCESS	ENERGY (kWh)	WATER (Liter)	MATERIAL (Kg)	WASTE (Kg)	TRANSPORTATION (Km)	EMISSIONS (Kg)	BIODIVERSITY (Ha)
			WASTE				
Soaking	0	57	0	3	0	0	0
Washing	0	255	0	5	0	0	0
Griding	0	0	0	2	0	0	0
Cooking	0	0	0	0	0	392	0
Filtering	0	0	0	754	0	0	0
Sedimentation	0	1523	0	0	0	0	0
Molding	0	82	0	0	0	0	0
Total	0	1917	0	764	0	392	0

2.4 GPI

The Green Productivity Index (GPI) is the ratio between the company's productivity value, referred to as the economic index, and the environmental impact value, known as the environmental index [4]. Gas emissions, water usage, solid waste, and land waste are the four environmental variables of GPI, derived from the analysis of seven types of waste in GVSM.

Economic Index. The economic indicator is used to determine the amount of revenue compared to production costs. The calculation of the economic index in this study can be seen in Table 4.

Table 4. Economic Index

NUM	PRODUCTION DETAILS	DESCRIPTION	CALCULATION	QUANTITY (Rp.)
A	REVENUE (Rp)			
1	Tofu Price	Rp.500.00	Tofu Price X Tofu Quantity	1,875,000.00
2	Tofu Quantity	3,750 pieces		
B	PRODUCTION COST (Rp)			
1	Raw Materials	Rp.670,000.00		1,554,000.00
2	Labor Cost	Rp.134,000.00		

NUM	PRODUCTION DETAILS	DESCRIPTION	CALCULATION	QUANTITY (Rp.)
3	Overhead Cost	Rp.750,000.00	Raw Materials + Labor Cost + Over-head Cost	
ECONOMIC INDEX				
1	Revenur	Rp.1,875,000.00	Revenur / Produc-tion Cost	1.21
2	Production Cost	Rp.1,554,000.00		

Environmental Index. The environmental indicator is the accumulation of different types of environmental variables. Each indicator value is obtained by multiplying the weight, based on experts from the Environmental Sustainability Index (ESI), with the amount of waste generated during the production process. The calculation of environmental index variables in this study can be seen in Table 5.

Table 5. Environmental index Variables

NUM	PRODUCTION PROCESS	DESCRIPTION	WASTE QUANTITY	TOTAL WASTE
A	**SOLID WASTE GENERATION (SWG)**			
1	Soaking	Husk Waste	3	
2	Washing	Husk Waste	5	764.00
3	Grinding	Absorbent Waste	2	
4	Filtering	Tofu Dregs Waste	754	
B	**WATER CONSUPTION (WC)**			
1	Soaking	Soaking Water	57	
2	Washing	Washing Water	255	1,917.00
3	Sendimentation	Sendimentation Water	1,523	
4	Molding	Molding Water	82	

After obtaining the detailed values of the environmental indicator variables, the environmental indicator value can be calculated. In the case of Pak Sadino's tofu industry, the ESI weight values for the two variables are 0.33 for Solid Waste Generation (SWG) and 0.67 for Water Consumption (WC). Once the variable weights are determined in the GPI, the environmental Index value can be calculated, as shown in Table 6.

Table 6. Environmental index

NUM	ENVIRONMENTAL INDEX	ENVIRONMENTAL INDEX VALUE	ESI WEIGHT	EI VALUE
1	SWG	764.00	0.33	252.12
2	WC	1,917.00	0.67	1,284.39
	TOTAL ENVIRONMENTAL INDEX			1,536.51

The result of the ESI weighting is an environmental indicator value of 1.53651 tons in the production process. With the economic indicator value of 1.21 and the environmen-

tal indicator value of 1.53651, the GPI can be calculated by dividing the economic in-
dicator by the environmental indicator, resulting in a GPI of 0.785. This result indicates
that the green productivity value is still low because the economic indicator is lower
than the environmental indicator.

2.5   Determination of the Problem Productivity Value

The issues can be identified from several sources, including mass balance, productivity,
GVSM, and GPI calculations. The mass balance indicates that the highest waste value
is found in the sedimentation process, with a value of 1,523 kg. In productivity, the
lowest value is seen in sedimentation waste, with a value of 36.59%. According to
GVSM, the most significant waste is liquid waste, totaling 1.917 liters. The GPI value
of 0.785 indicates that productivity is not stable, as the environmental indicator is
higher than the economic indicator. From this explanation, it can be concluded that the
problems are present in the sedimentation process and the type of liquid waste.
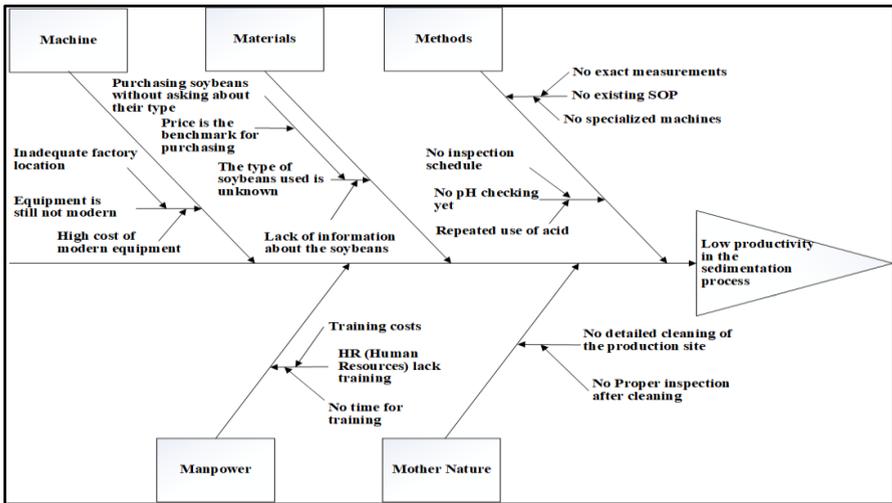
2.6   Fishbone Diagram

Fig. 1. Fishbone Diagram

From the explanation in the previous stage, the main problem can be identified using a
fishbone diagram. Each cause can display several sub-categories, which can branch out
into more sub-categories, showcasing various causes related to the issues presented.
The content of the fishbone diagram resulting from the discussion with Pak Sadino can
be seen in the Fig. 1.

3   Results and Discussion

Based on the previous results, it was found that the highest waste generation and the lowest productivity values occur in the sedimentation process, specifically concerning liquid waste. Therefore, it is essential to establish objectives and main targets related to green productivity and identify alternative solutions to address these issues.

3.1   Determination of Goals and Main Targets Related to Green Productivity

After identifying the issues related to productivity and environmental performance, the next step is to formulate the objectives and desired targets for Pak Sadino's tofu factory. The main objectives and targets can be seen in Table 7.

Table 7. Determination of Goals and Main Targets Related to Green Productivity

NUM	MAIN ISSUES RELATED TO GREEN PRODUCTIVITY	GOALS	TARGETS
1.	From the mass balance calculations, it can be determined that the main problem lies in the large amount of liquid waste produced during the sedimentation process n	Develop and determine alternative solutions for liquid waste treatment to reduce liquid waste disposal	Alternative solutions that can reduce liquid waste disposal.
2.	From the calculation of the GPI value, the main issue identified is that the environmental indicators are higher than the economic indicator	Create and identify alternative solutions that can enhance the GPI value	Alternative solutions that can increase the GPI value using a Green Productivity (GP) approach

3.2   Formulation of Alternative Solutions Related to Green Productivity

In the previous stage, the targets and objectives for addressing the existing issues were established, where the highest waste is generated during the sedimentation process, particularly in liquid waste. Based on this, the next step is to outline alternative solutions that can resolve or at least minimize these problems. The proposed alternative solutions are as follows.

Soy Sauce Production. The production of soy sauce is one alternative solution used to reduce environmental impacts. Making soy sauce using liquid waste from tofu production will result in a soy sauce of quality grade 2. The other ingredients used in the soy sauce production process include coconut sugar, sesame, galangal, garlic, candlenuts, star anise, kaffir lime leaves, bay leaves, and lemongrass. The tools used in the process are a stove, pot, filtering cloth, wooden stirrer, scale, funnel, and soy sauce bottles. An example of the soy sauce production process from tofu waste can be seen in Fig. 2.

Fig. 2. Soy Sauce Production

Organic Fertilizer Production. Processing liquid waste into organic fertilizer is one alternative solution for addressing the issue of liquid waste from tofu production. The liquid waste can be repurposed to recycle tofu waste. The liquid waste from tofu production contains a complete range of nutrients, including macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), as well as micronutrients: iron (Fe), copper (Cu), manganese (Mn), molybdenum (Mo), zinc (Zn), chlorine (Cl), and boron (B). The materials and tools needed for making this organic fertilizer include tofu liquid waste, activator liquid (EM4), granulated sugar, coconut water, and water. An example of the organic fertilizer product made from tofu waste can be seen in Fig. 3.

Fig. 3. Organic Fertilizer Production

Edible Film Production. Edible film is one product that can be produced using liquid waste from tofu, making it a potential solution for the issue of liquid tofu waste. Tofu wastewater can be used as a raw material for making edible films. The production process requires equipment such as a 1000 mL beaker, sealed glass jars, pipettes, a blender, knife, digital scale, fermentation container (baking pan), newspaper, gauze, metal ruler,

rubber, hot plate, and oven. The materials needed for this process include tofu produc-
tion wastewater, edible flower (arum flower), Acetobacter xylinum starter from pine-
apple, coconut water, granulated sugar, ammonium sulfate (ZA), glacial acetic acid,
aquades, and glycerol. An example of the edible film product made from tofu waste can
be seen in Fig. 4.

Fig. 4. Edible Film Production

3.3   Formulation of Alternative Solutions Related to Green Productivity.

To determine alternative solutions, interviews were conducted that included questions
about the weighting scale of the alternatives, weight calculations, and data processing
using pairwise comparison with the assistance of Microsoft Excel. The priority scale
for the alternative weights can be seen in the Table 8.

Table 8. Respondent Assessment

Alternatives	Soy Sauce	Organic Fertilizer	Edible Film
Soy Sauce	1.00	9.00	3.00
Organic Fertilizer	6.00	1.00	3.00
Edible Film	2.00	8.00	1.00
Total	**9.00**	**18.00**	**7.00**

After obtaining the respondent assessment data, the weight values were calculated to
determine the selected alternative, as shown in Table 9.

Table 9. Weight Calculations

Alternatives	Soy Sauce	Organic Fertilizer	Edible Film
Soy Sauce	0.11	0.67	0.22
Organic Fertilizer	0.50	0.06	0.44
Edible Film	0.43	0.43	0.14
Weight	**0.35**	**0.38**	**0.27**

From the weight calculations, it is known that the alternative with the highest weight value is the production of organic fertilizer, with a value of 0.38. After determining the selected weight, it is necessary to calculate the consistency ratio (CR) to determine whether the calculations are justifiable (correct) or not. To perform the CR calculation, values from the consistency index (CI) and the maximum eigenvalue of the matrix are needed. The eigenvalue calculation for matrix 1 can be seen in Table 10

Table 10. Eigen Matrix 1

Alternatives	Soy Sauce	Organic Fertilizer	Edible Film	Total
Soy Sauce	0.35	3.45	0.81	4.61
Organic Fertilizer	2.08	0.38	0.81	3.27
Edible Film	0.69	3.07	0.27	4.03

After obtaining the value of eigen matrix 1 can be calculated with eigen matrix 2 by dividing the total value by the weight of each alternative, the results of which are as in Table 11.

Table 11. Eigen Matrix 2

Alternatives	Total	Weight	Total/Weight
Soy Sauce	4.61	0.35	13.30
Organic Fertilizer	3.27	0.38	8.53
Edible Film	4.03	0.27	14.94
Eigen Matrix			12.26

After obtaining the value of the eigenvalue matrix, the consistency index (CI) can be calculated using the formula $(\lambda max - n):(n-1)$, resulting in a value of 4.63. Next, the consistency ratio (CR) is calculated by dividing the CI value by the consistency index (CI) of 0.58, yielding a CR value of 7.98. A CR value of 7.98 indicates that the calculations can be considered valid, as it is less than or equal to 0.1, specifically 7.98.

4   Conclusion

From the analysis of productivity and environmental performance using the Green Productivity approach in Pak Sadino's tofu industry, it can be concluded that the GPI value of 0.785, which is less than 1, indicates that green productivity during the production process is not yet optimal. The highest type of waste identified is liquid waste, amounting to 1,917 liters. After determining the causes of low productivity and selecting alternative solutions to the problems, the production of organic fertilizer was chosen as the selected alternative solution due to its highest weight value of 0.38.

and does not necessarily represent the official views of the Engineering Faculty, Mulawarman University.

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