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Proposed management of nata de coco production waste with green productivity (Case study in UKM Usaha Tani Lebak)

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ABSTRACT

UKM Tani Lebak is an industry that processes coconut water into nata de coco. During production, water use could be more efficient. Apart from that, there are also rejected products and production waste that pollute the environment. So, based on this, it is necessary to measure and evaluate productivity and environmental performance. This research aims to determine the value of productivity and the green productivity index (GPI) and to propose alternative improvement solutions to increase productivity and reduce environmental impacts. The method used to solve this problem is green productivity, starting with calculating material balance during production, then creating green value stream mapping and calculating GPI. The calculation results show that the productivity value moved from 1.335 to 1.336. UKM Tani Lebak can use three alternative solutions to increase productivity while reducing environmental impacts. The best alternative is to combine the neutralization and washing processes, which produces a GPI from 0.6882 to 0.927. This value shows a better ratio of productivity to environmental impact.

ABSTRAK

UKM Usaha Tani Lebak adalah industri yang mengolah air kelapa menjadi nata de coco. Saat berproduksi terjadi in-efisiensi pada penggunaan air. Selain itu, terdapat juga produk gagal dan limbah produksi yang mencemari lingkungan. Sehingga, berdasarkan hal ini perlu dilakukan pengukuran dan evaluasi produktivitas serta kinerja lingkungan. Tujuan penelitian ini adalah menentukan nilai produktivitas dan indeks produktivitas hijau (GPI) serta mengusulkan alternatif solusi perbaikan untuk meningkatkan produktivitas dan mengurangi dampak lingkungan. Metode yang digunakan untuk menyelesaikan permasalahan tersebut yaitu produktivitas hijau, dimulai dengan menghitung keseimbangan material saat proses produksi, kemudian diikuti dengan pembuatan green value stream mapping dan perhitungan GPI. Hasil perhitungan menunjukkan, nilai produktivitas bergerak dari 1,335 menjadi 1,336. Terdapat tiga alternatif solusi yang dapat digunakan untuk meningkatkan produktivitas sekaligus mengurangi dampak lingkungan. Alternatif terbaik yaitu menggabungkan proses netralisasi dan pencucian, yang menghasilkan GPI dari 0,6882 menjadi 0,927. Nilai ini menunjukkan rasio produktivitas terhadap dampak lingkungan yang lebih baik.

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1. Introduction

The agro-industry sector has the most significant potential for development by utilizing raw materials from agricultural products to support the economy in a region. In the third quarter of 2021, the agro-industry sector contributed to national growth by 8.86% or 51.16% to the development of the non-oil and gas processing industry, where the food and beverage industry as a subsector of agro-industry contributed by 38.91% [1]. As an economic driver in a region, a high level of productive production in an agro-industrial SME is crucial [2]. Productivity is one of the driving factors for the advancement of a company to compete effectively with other enterprises.

UKM Usaha Tani Lebak consistently strives to meet the demand yet often needs help to fulfil the requested quantities. Due to various factors, the primary contributor is the occurrence of non-product outputs (NPOs), such as failed or rejected nata de coco, as well as discarded fermentation byproducts

without proper waste management. Additionally, in the nata de coco production process at UKM Usaha Tani Lebak, efficiency in water usage needs to be adequately addressed, resulting in high energy costs. Both these factors undoubtedly impact productivity, leading to lower output and increased energy expenses. In addition to the issues related to productivity, challenges arise from the waste generated during the nata de coco production process. This issue stems from inadequate waste handling and management practices. Liquid waste from nata de coco production carries high acidity (pH) and organic pollutant concentration [3]. High organic content in the waste is considered a pollutant due to its potential to deplete dissolved oxygen in water, disrupting the environmental ecosystem [4]. If these problems persist without preventive or corrective measures, environmental pollution from waste contamination will inevitably occur.

To effectively measure and enhance productivity while mitigating environmental impact, the green productivity approach is employed to identify alternative improvement solutions. The Green Productivity approach generates environmentally friendly outputs by implementing technical aspects, technological utilization, and systemic management [5]. In addition to process modifications to reduce waste output, supportive improvement efforts are crucial. These endeavors aim to prevent waste generation from technical aspects that cannot be quantified with the Environmental Performance Index (EPI) and or to reduce waste discharge resulting from the production process.

2. Research Method

This study aims to determine productivity values and GPI, followed by enhancing productivity and reducing the adverse environmental impact of waste through the best proposed alternative improvements. The proposed improvement alternative is focused on waste prevention through process modifications. The result will derive alternative improvement solutions to prevent waste generation by comparing GPI values using the green productivity method.

The stages of research activities conducted in this study are outlined based on the steps of green productivity methodology, which include getting started, planning, and generation and evaluation. Getting started step involves conducting a walk-through survey and collecting data by identifying production process flows. The Planning step entails identifying the sources and causes of problems and determining the objectives and targets to be achieved in order to resolve the issues. At this stage, a mass balance is made, and then the current green value stream mapping (GVSM) is developed so that the environmental impact and initial GPI can measure the current productivity value. The generation and evaluation step involve formulating or arranging alternative solutions using the EPI value measurement method. Alternative improvement solutions are designed in this stage, and productivity and GPI values are estimated after repair. Finally, create future green value stream mapping based on the best solution.

3. Result and Discussion

3.1. Mass Balance

In this study, a mass balance is constructed to determine the input and output of the nata de coco production process. Before elaborating on the mass balance based on each process, Table 1 shows the outlines input and output.

Table 1. Input and Output of Nata de Coco Production

Process	Input		Output			
	Material	Qty (*kg*)	Product		Non Product	
			Type	Qty (*kg*)	Type	Qty (*kg*)
Filtration	Coconut Water	200	Clean Coconut Water	199.8	Dirt	0.2
	Clean Coconut Water	199.8			Mass loss of water	26.04
	Sugar	20			Charcoal & Ash	9.6
Boiling	ZA Fertilizer	1	Boiled Coconut Water	196.76	Mass loss of firewood	6.4
	Vinegar Acid	2				
	Firewood	16				
Clarification	Boiled Coconut Water	196.76	Solution in tray	196.76	-	-
Cooling	Solution in tray	196.76	Room temperature solution	196.76	-	-
Starter Addition	Room temperature solution	196.76	Coconut water solution + starter	216.76	-	-
	Starter	20			-	-
	Newspaper	1	Newspaper	1	-	-
Fermentation	Coconut Water Solution + Starter	216.76	Fermented nata de coco	197.06	Mass loss of fermentation	19.70
	Newspaper	1	Newspaper	1		
Harvesting	Fermented nata de coco	197.06	Crusted nata de coco sheet	156.96	Fermented liquid	39.41
					Rejected nata	0.69
	Newspaper	1			Used Newspaper	1
	Water	200			Tray washing liquid	200
Peeling	Crusted nata de coco sheet	156.96	Nata de coco sheet	144.4	Sheet waste	7.85
					Rejected part waste	4.71
Neutralization	Nata sheet	144.4	Neutral nata	144.4	Neutralized residual water	600
	Water	600				
Washing	Neutral nata	144.4	Cleaned nata	144.4	Washing water	600
	Water	600				
Cutting	Cleaned nata	144.4	Cutted nata	144.4	-	-
Pressing	Cutted nata	144.4	Pressed nata	101.08	Residual pressing water	43.32
Packaging	Pressed nata	101.08	Packed nata	101	Nata Sisa	0.08

Table 1 indicates that the nata de coco production process comprises 13 processes. The production quantities in Table 1 are based on daily production amounts. In a single daily production process, 200 liters of coconut water are used, resulting in 144.31 kg of sliced nata de coco. After pressing to remove moisture content to transport nata de coco products easily, approximately 101 packages of nata are produced per kilogram. The mass balance in Figure 1 can obtain a more detailed insight into material flow, product yields, and waste generation. Significant material changes occur during the boiling, fermentation, and harvesting processes. The most abundant waste is liquid waste from the neutralization and washing processes. Solid waste is the second most prevalent waste in the nata de coco production process.

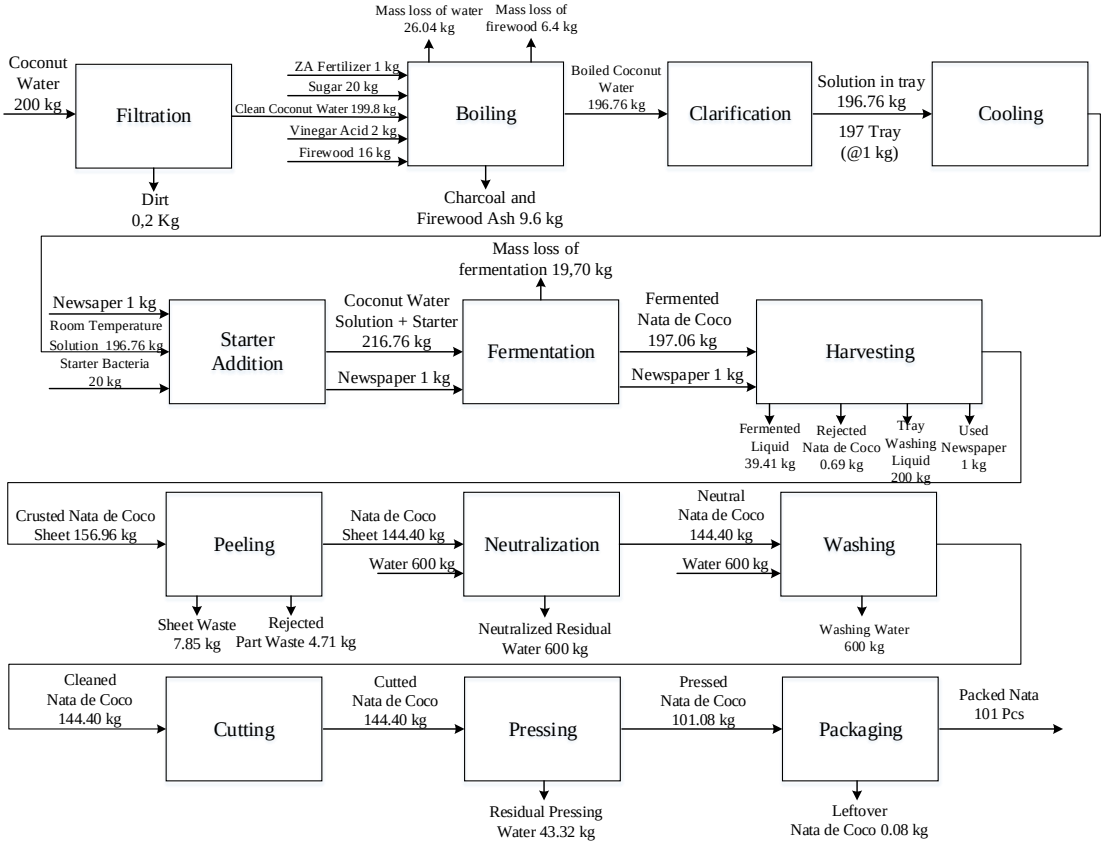

Figure 1. Mass Balance of Nata de Coco Production

3.2. Current GVSM

The energy required for each nata de coco production process is 0.74165 kWh, derived from the water pump, pressing, and cutting machines. The wastewater generated amounts to 1482.7 litres, originating from residual fermentation liquid, residual tray washing liquid, residual neutralization liquid, residual washing liquid, and residual pressing liquid. Waste materials total 45.74 kg, originating from boiling water and fermentation losses. The generated solid waste amounts to 24.13 kilograms, consisting of residue from the filtration process, ash and wood charcoal, used newspapers, failed nata de coco, coconut husks, unfit nata de coco portions, and leftover nata de coco. CO2 emissions produced 28 kg of CO2 from the combustion of wood fuel during the boiling process. The following, as shown in Figure 2, is the current Green Value Stream Mapping (GVSM) diagram of the nata de coco production process.

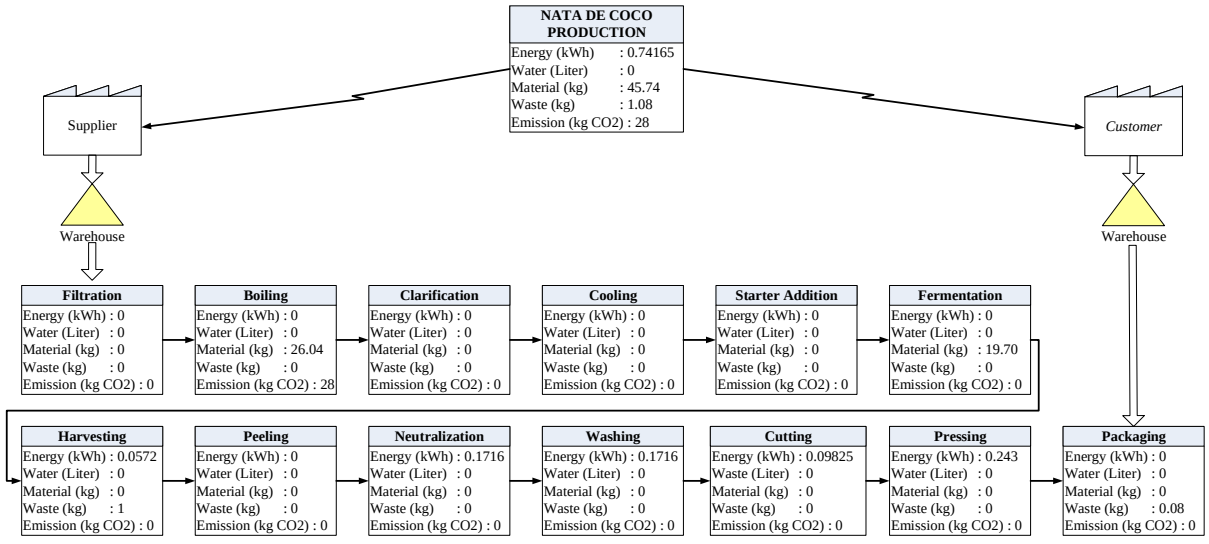

Figure 2. Current Green Value Stream Mapping (GVSM)

From the current GVSM diagram in Figure 2, It can determine the amount of energy, emissions, and waste generated in each nata de coco production process. The energy required is 0.74165 kWh, wastewater amounts to 1482.7 liters, waste material totals 45.74 kg, solid waste generated is 24.13 kg, and CO2 emissions produced are 28 kg CO2. Consequently, it attains that liquid waste is the most prominent cause.

3.3. Current Productivity Value, Environmental Impact, and Green Productivity Index

The nata de coco production productivity at UKM Usaha Tani Lebak is measured using input and output data. Green productivity can consider the productivity value of UKM Usaha Tani Lebak in producing nata de coco excellent and stable. In Figure 3, the total productivity of UKM Usaha Tani Lebak in 2022 experienced fluctuations, both increases and decreases, in each month. The productivity level of the nata de coco production process each month ranged from 1.2 to 1.4. If the productivity value is greater than or equal to 1 ($P \geq 1$), it means that the output exceeds the input used [6-9]. Considering the amount of input and output and the productivity value indicates that the productivity level in the nata de coco production process at UKM Usaha Tani Lebak is good. However, enhancing productivity can improve through improvements capable of increasing profitability.

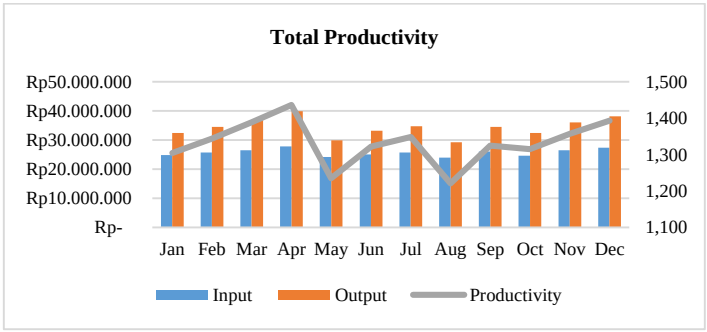

Figure 3. Total Productivity UKM Usaha Tani Lebak

The definition of productivity is the output produced per input unit [10]. In the nata de coco production process at UKM Usaha Tani Lebak, the total input was Rp 308,359,309, and the total output was Rp 411,670,000. Consequently, the total productivity value in the current condition is 1.335. This ratio indicates that every Rp 1 input generates Rp 1,335 output, suggesting that UKM Usaha Tani Lebak is profitable. This productivity value is influenced by various factors such as the availability of raw materials, the success of the fermentation process, the availability of tray containers, the number of workers, demand volume, and the quantity of rejected or failed products.

Table 2. Input and Output of Nata de Coco Production

Current GVSM	Production Qty. (*kg*)	Production Freq. (*per month*)	Waste Type				
			Energy (*kWh*)	Water (*L*)	Material (*kg*)	Trash (*kg*)	Emission (*kg CO2*)
			0.74165	**1,482.73**	**45.74**	**24.13**	**28**
January	9,250	92	68.23	136,411.16	4,208.08	2,219.96	2,576
February	9,870	98	72.68	145,307.54	4,482.52	2,364.74	2,744
March	10,520	105	77.87	155,686.65	4,802.7	2,533.65	2,940
April	11,405	113	83.81	167,548.49	5,168.62	2,726.69	3,164
May	8,530	85	63.04	126,032.05	3,887.9	2,051.05	2,380
June	9,480	94	69.72	139,376.62	4,299.56	2,268.22	2,632
July	9,910	99	73.42	146,790.27	4,528.26	2,388.87	2,772
August	8,340	83	61.56	123,066.59	3,796.42	2,002.79	2,324
September	9,870	98	72.68	145,307.54	4,482.52	2,364.74	2,744
October	9,250	92	68.23	136,411.16	4,208.08	2,219.96	2,576
November	10,290	102	75.65	151,238.46	4,665.48	2,461.26	2,856
December	10,905	108	80.10	160,134.84	4,939.92	2,606.04	3,024
	Total		**866.98885**	**1,733,311.37**	**53,470.06**	**28,207.97**	**32,732**

Table 2 denotes that nata de coco production required 866.98885 kWh of energy. Additionally, nata de coco production during research resulted in 1,733,311.37 liters of wastewater, 53,470.06 kg of waste material, 28,207.97 kilograms of solid waste, and 32,732 kg of CO2 emissions. The most abundant waste generated is liquid waste originating from residual tray washing water, residual neutralization water, residual nata de coco washing water, residual pressing water, and residual fermentation liquid. Hence, liquid waste is the most prominently generated waste. The ratio of solid, liquid, and gas waste is 0.94: 0.04: 0.02. The nata de coco production process generates solid, liquid, and gas waste, so the GPI indicators determined are gaseous waste generation, water consumption, and solid waste generation. After obtaining the weights of the green productivity indicators, including GWG, WC, and SWG, the EI value is determined, resulting in 1.9375. A higher EI value indicates a more significant environmental impact on the production process [11].

By dividing the current condition productivity value and EI, the current condition GPI value is 0.6882. This value is an index indicating the balance between productivity and environmental impact in the present condition. Generally, a higher GPI index value implies more elevated levels of productivity and economic indicators, while the environmental effects resulting from the production process are lower [12]. GPI can measure performance during sustainable improvement. The higher the GPI value for a condition or alternative, the better the ecological impact, signifying its selection as the preferred choice [13].

3.4. Designing Optimal Alternative Improvement Solutions with Estimated Productivity Value and Green Productivity Index

The alternative improvement solutions aim to reduce the environmental impact of the nata de coco production process and enhance the company's productivity. Alternative solutions with a green productivity approach focus on waste prevention through process modifications. These alternative improvement solutions are designed to address liquid waste, the most abundant type of waste generated by the nata de coco production process. The selection of improvement alternatives is based on estimates of productivity and GPI.

Table 3. Recapitulation of Estimated Value of Repair Solutions

No.	Scenario	Productivity	EI Value	GPI Value
1.	Current Condition	1.335	1.9375	0.6882
2.	Alternative Solution 1	1.33533	1.86775	0.714
3.	Alternative Solution 2	1.33528	1.8355	0.727
4.	Alternative Solution 3	1.33587	1.4405	0.927

The use of the Three Compartment Sink concept in the tray washing process and three washing containers, each with a capacity of 24 liters, for washing approximately 197 trays are suggested. Cleaning with the Three Compartment Sink method (immersion method with three containers) consists of a washing container (wash), a rinsing container (rinse), and a final rinsing container (final rinse) [13]. After half of the total trays in a single production cycle have been washed, the water is changed once for all three containers. From this alternative improvement solution, the estimated total productivity value is 1.33533 due to electricity savings in the water pump machine amounting to Rp 69,553.78 per year. This alternative solution can reduce wastewater from tray washing from 200 kg per single production cycle to 144 kg, a reduction of approximately 28%. The estimated removal of potential water pollution from tray-washing wastewater is about 65,464 liters per year. The decline in potential liquid waste pollution is related to a decrease in the water consumption indicator, which is 7,089 liters. The estimated EI value is 1.689, and the GPI value is 0.714.

The second alternative proposes using water tap aerators in the tray-washing process. Two water tap aerators are installed according to the number of water taps available. An aerator is an attachment at the end of the fixture that filters the water flow. Using aerators can restrict the flow from the tap and reduce water consumption by approximately 20.5% [14]. From this alternative improvement solution, the estimated total productivity value is 1,33528 due to electricity savings in the water pump machine amounting to Rp 56,995.45 per year. This alternative solution can reduce wastewater from tray washing from 200 liters per single production cycle to 118 liters. The estimated reduction in potential water pollution from tray-washing wastewater is about 95,858 kg annually. The reduction in potential liquid waste pollution is related to a decrease in the water consumption (WC) indicator, which is 6,960 liters. Therefore, the estimated EI value is 1.8355, and the GPI value is 0.727.

The last alternative is a combination of the neutralization and nata de coco washing processes. After immersion, a rinsing process is performed using 200 liters of clean water with a drum. According to the nata de coco production procedure in the "Module for Food Production for Household Industry: Packaged Nata de Coco" by the Food and Drug Monitoring Agency, nata de coco sheets that have had the mucus or husk removed are then neutralized without rinsing again [15]. The neutralization process can already clean the nata residue after immersion. From this alternative improvement solution, the estimated total productivity value is 1.33587 due to electricity savings in the water pump machine amounting to Rp 193,204.9 per year. This alternative solution can reduce wastewater from nata de coco washing by 400 liters per single production cycle. The estimated reduction in potential water pollution due to nata de coco washing wastewater is about 467,600 liters per year. The decline in potential liquid waste pollution is related to a decrease in the water consumption (WC) indicator, which is 5,380 liters. Therefore, the estimated EI value is 1.4405, and the GPI value is 0.927. Based on the highest productivity and GPI values, as shown in Table 3, alternative solution 3 becomes the best alternative improvement solution.

3.5. Future Green Value Stream Mapping (GVSM) Based on Best Alternatives

In this study, GVSM is created in two conditions: the current and future conditions. GVSM in the present state shows the amount of waste in the disease before improvement or the current situation. Meanwhile, GVSM, in the future condition, shows an estimated representation of the amount of waste after modification by implementing the best alternative improvement solutions based on the green productivity approach.

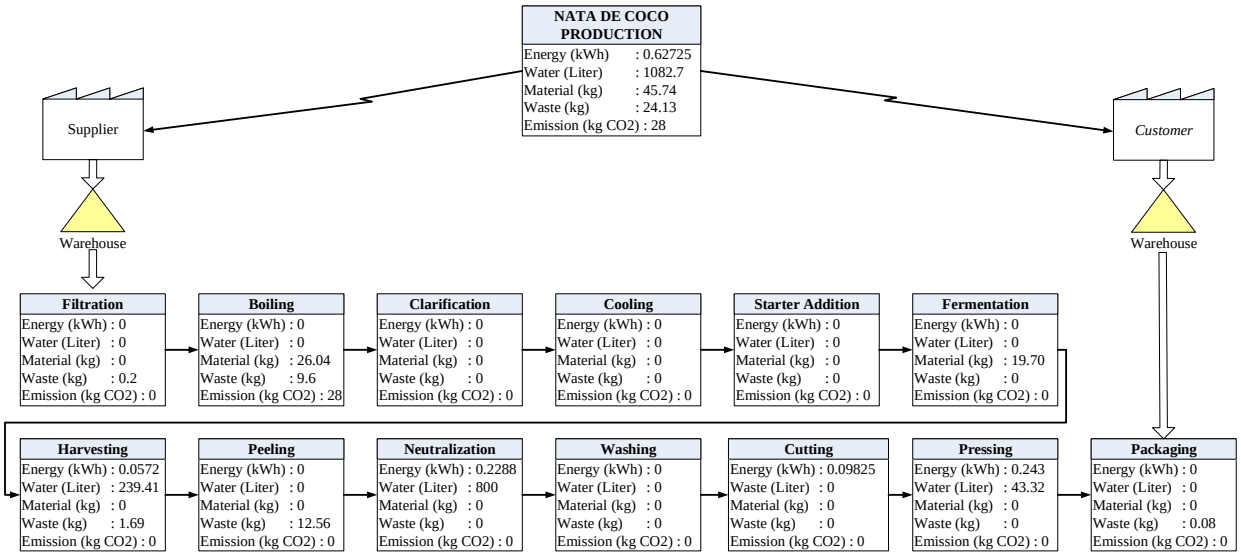

Figure 4. Future GVSM (Alternative Improvement Solutions with Green Productivity)

The best alternative improvement solution obtained through the green productivity method is the combination of neutralization and washing processes of nata de coco. Through this alternative, Figure 4 shows the values of each waste produced in each process in the future condition. An estimated reduction in importance can be observed due to the proposed improvements, such as the reduction in the amount of energy used and the amount of wastewater generated. The estimated energy required for each nata de coco production process is 0.62725 kWh, wastewater generated is 1,082.7 liters, waste material is 45.74 kg, waste is 24.13 kg, and CO2 emissions is 28 kg CO2. The reduction in wastewater is due to the reduced use of clean water in the washing process. It is also related to the decrease in electricity consumption due to the reduction in the use of water pump machines during the process.

In the current condition, the neutralization and washing processes are the most significant contributors to wastewater, each producing 600 liters. Through the best alternative improvement solution using the green productivity method, it can be estimated that there will be a decrease in energy required for each production process of nata de coco by 0.1144 kWh or 15.43%, from the original 0.74165 kWh to 0.62725 kWh. Additionally, there will be a reduction in wastewater generated by 400 liters or 26.98%, from the original 1,482.7 liters to 1.082,7 liters. From this comparison, the proposed improvement solution can reduce waste, improve energy efficiency, and reduce wastewater in the production process of nata de coco, thereby reducing its environmental impact and increasing productivity.

4. Conclusion

The waste issue in every stage of coconut jelly production includes solid, liquid, and gas waste originating from the filtering, boiling, harvesting, peeling, neutralization, washing, and pressing processes. The current total productivity value is 1.335, with a GPI (Green Productivity Index) of 1.9375. The best alternative improvement solution using the green productivity method is the combination of the neutralization and washing processes of coconut jelly, with a future productivity value of 1.336 and a GPI of 0.927.

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