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Optimizing Productivity and Efficiency Using Eco-Efficiency Method at PT XYZ

Nur Latifa Hendriana[1]*, Wiwik Handayani[2]
Universitas Pembangunan Nasional "Veteran" Jawa Timur
Corresponding Author: Nur Latifa Hendriana
21012010249@student.upnjatim.ac.id

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A B S T R A C T

This study aims to evaluate the productivity and efficiency of cheddar cheese production using an eco-efficiency approach at PT XYZ. The research addresses the underutilization of whey waste by integrating quantitative analysis of productivity, efficiency, and the Eco-Efficiency Index (EEI), followed by qualitative insights through in-depth interviews. Data were collected via observation, documentation, and lab testing from January to April 2025. Results indicate stagnant productivity and low efficiency, primarily due to unprocessed whey waste, which constitutes over 89% of input. The study proposes converting whey into liquid organic fertilizer as a viable solution, offering environmental benefits and potential profit, contributing to sustainable operations in the dairy industry.

INTRODUCTION

Industrial waste management has emerged as a strategic concern in Indonesia due to its adverse impacts on environmental quality and public health. The food and beverage sector, one of the country's largest industrial contributors, generates substantial volumes of solid and liquid waste that are often inadequately treated. In 2024, the National Waste Management Information System (SIPSN, 2024) reported 29.37 million tons of waste generated nationwide, of which only 61.59% was successfully managed, leaving 38.41% unmanaged and contributing directly to environmental degradation. While solid waste receives considerable attention, liquid waste management remains underdeveloped, despite its complex pollutant characteristics and greater difficulty in environmental recovery.

A notable example is whey, a by-product of the dairy processing industry, which contains 95.1% water, 0.85% protein, 0.27% fat, 4.7% lactose, along with vitamins and minerals (Estikomah et al., 2023; Poonia et al., 2023; Zotta et al., 2020). Its high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels can cause eutrophication and oxygen depletion in aquatic ecosystems if discharged untreated. Globally, whey production reaches 40.7 million tons per year, with the European dairy industry utilizing up to 60–70% for high-value products such as liquid fertilizers, whey-based beverages, and animal feed. In contrast, whey utilization in Indonesia remains minimal, resulting in both environmental loss and untapped economic potential.

PT XYZ, a medium-scale cheddar cheese producer, illustrates this inefficiency. Between 2022 and 2024, the company processed 461,150 liters of milk, yielding 50,737.44 kg of cheese and generating 410,412.56 liters of whey—approximately 89% of the total input—discarded without further processing. On average, 10 liters of milk produce only 1 kg of cheese, with the remaining 9 liters becoming waste. This inefficiency is compounded by low profitability, with 2024 gross profit margins ranging from 1.5% to 2.9% per month due to high production costs consuming up to 97% of revenue and fluctuating selling prices between Rp200,000–Rp250,000/kg.

International practices, including those in Egypt, Algeria, Tunisia, and Morocco, demonstrate that integrating economic and environmental performance—known as the eco-efficiency approach—can transform whey from a waste stream into a profitable resource, reduce production costs, and mitigate environmental impact (Mukherjee, 2023; Oduro, 2024). Composting, for instance, is a low-cost and environmentally friendly option for recycling whey's organic content into liquid fertilizer (Nurhidayanti & Khawari, 2020). However, existing research in Indonesia has been largely sectoral, focusing on technical treatment methods or isolated productivity analyses, with limited integration of waste recycling into broader operational efficiency frameworks—particularly in the cheese industry.

This research addresses that gap by evaluating productivity and efficiency in whey waste management at PT XYZ through an eco-efficiency framework. The study aims to measure operational performance while minimizing environmental impacts, providing empirical evidence on how waste utilization can enhance both profitability and sustainability. Findings are expected to contribute theoretically to the field of sustainable operations management and practically to the development of waste valorization strategies in Indonesia's dairy industry.

THEORETICAL REVIEW

Operational Management

Explanation of theory here

Operational management is often defined as planning, organizing, directing, and controlling the production of goods and services to achieve efficiency and effectiveness (Safitri et al., 2022). While this definition is foundational, it tends to simplify the complexity of contemporary operations. The traditional view, focusing on cost minimization and throughput, does not fully capture the challenges faced in volatile, uncertain, complex, and ambiguous (VUCA) environments. For instance, supply chain disruptions, digitalization, and sustainability pressures mean that operational managers must not only optimize resources but also ensure resilience and adaptability. The evolution from Manufacturing Management and Production Management to Operations Management demonstrates this shift — operations is no longer a back-end function but a strategic capability for competitiveness (Agustyn et al., 2024). However, many firms still treat operations narrowly, prioritizing cost over flexibility and sustainability, which can undermine long-term performance.

Sustainable Operations Management

Sustainable operations management applies economic, environmental, and social principles (Opoku & Li, 2025; Syamil, 2023). While the Triple Bottom Line (profit, planet, people) offers a comprehensive lens, critics argue it risks becoming symbolic if not supported by measurable practices. In reality, firms often emphasize economic gains while downplaying environmental and social dimensions, leading to "greenwashing." Institutional and stakeholder theories (Mukherjee, 2023) highlight that sustainability is not merely voluntary but shaped by external pressures such as regulation, customer demand, and NGO activism. Thus, sustainable operations must go beyond compliance, embedding practices like resource efficiency, waste minimization, and collaborative supply chain governance. Yet, the challenge remains in balancing trade-offs: cost efficiency may contradict environmental goals, and social welfare is often the least prioritized due to its intangible measurement.

Productivity

Productivity measures the ratio of output to input, with improvement signifying higher efficiency and effectiveness (Dwimas et al., 2023; Heizer et al., 2023; Wali & Handayani, 2022). Key elements include efficiency, effectiveness, and quality. Types include total productivity, partial productivity (labor, material, capital, energy), and total factor productivity (Nasution et al., 2023). Here is the rumus of Productivity:

$$Productivity = \frac{output}{input} \text{ x } 100\% \text{ ....(1)}$$

Efficiency

Efficiency is traditionally associated with minimizing waste and costs to maximize output (Adam, 2024). However, this economic framing is often criticized for overlooking ecological boundaries and social externalities. For instance, in dairy processing, efficient equipment may reduce energy use, but if whey disposal is mismanaged, overall system efficiency remains questionable (Ranto, 2025). Hence, efficiency must be redefined in broader sustainability terms: not just producing more with less, but producing within ecological limits. Indicators such as water use intensity, waste reduction, and eco-efficiency provide a more holistic evaluation (Rofiq et al., 2023; Sugandi, 2024). Still, measurement challenges persist because efficiency is often context-dependent and may involve trade-offs across dimensions.

Eco-Efficiency

Eco-efficiency balances economic value creation with reduced environmental impact (Nurhidayanti & Khawari, 2020). Introduced by the WBCSD, it promotes resource productivity through cleaner production, material substitution, renewable energy, and recycling (He & Zhu, 2022; Oduro, 2024). Benefits include cost savings, regulatory compliance, and competitive advantage, with measurement methods such as output–input ratios, life cycle assessment, and the Eco-Efficiency Index.

Eco-Efficiency Index (EEI) quantitatively evaluates economic and environmental performance (Hartini & Yulianto, 2020). It is calculated as:

$$EEI = \frac{Price - Cost}{Eco\ cost + Cost} \qquad (2)$$

Products with EEI > 1 are sustainable, 0–1 affordable, and <0 unsustainable (Fairus & Murwaningsari, 2023). Eco-cost data in this study references Idemat 2024 (Goedkoop & van der Velden, 2024) due to the absence of direct waste treatment cost data.

Cause–Effect Diagram (Fishbone Diagram)

A visual tool for root cause analysis, categorizing contributing factors into people, methods, materials, machines, environment, and measurement (J. Heizer et al., 2017).

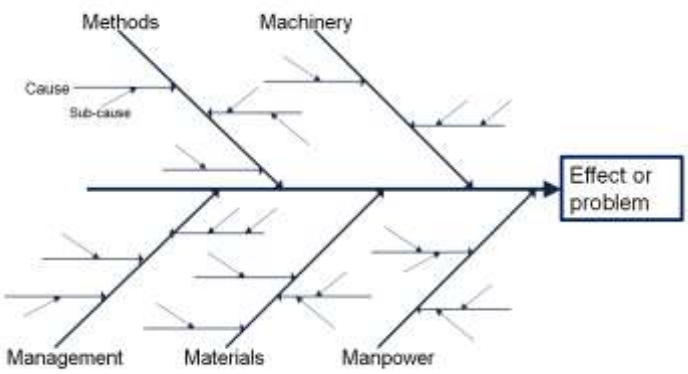

Figure 1. Fishbone diagram

Steps include problem identification, grouping causes, mapping main and minor causes, and determining corrective actions. Proven effective in improving product/service quality (Asyari & Nanggala, 2023; Hidayat & Saefulloh, 2022).

Non-Product Output (NPO)

NPO comprises outputs from production that are not the main product, such as waste, emissions, and energy losses (Oktafiyanti et al., 2024; Rofiq et al., 2023). Whey, comprising 80–90% of milk volume in cheese-making, is a significant NPO with high organic content. Classification includes liquid waste, solid waste, gaseous emissions, energy losses, and water losses. NPO measurement identifies inefficiencies and supports sustainability improvement.

METHODOLOGY

This study uses a descriptive quantitative–qualitative approach with an explanatory sequential design (Creswell & Creswell, 2018 in Yam, 2022), starting with quantitative data collection and analysis, followed by qualitative data to deepen and clarify results. The quantitative phase measures productivity, efficiency, and eco-efficiency from company observations and internal documentation, using input–output variables, environmental costs, and product yield. The qualitative phase involves purposive interviews with the operations manager, production manager, and finance staff to explore causes behind the data and evaluate readiness and challenges in waste management.

The research focuses on whey waste from cheese production at PT XYZ, particularly during curd–whey separation. Data were collected using triangulation (Sugiyono, 2022), combining observations (Jan–Apr 2025), interviews, and laboratory analysis of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and pH. Whey composition is 95.1% water, 0.85% protein, 0.27% fat, and 4.7% lactose (Estikomah et al., 2023; Poonia et al., 2023; Zotta et al., 2020) Secondary data from literature, eco-cost data (Goedkoop & van der Velden, 2024), and company records complemented the analysis. Quantitative data were processed using descriptive statistics, while qualitative data were analyzed descriptively, with results integrated for comprehensive findings.

RESULTS

Waste Identification

The waste identification process is based on observations on the material balance that has been carried out. The waste identification analysis aims to find out what waste is generated and how the impact of the waste is caused. The following is a detailed table:

Table 1. Waste Identification

Type of Waste	Form of Waste	Source of Waste	Waste Impact	Waste Quantity

Whey	Liquid	Separation curd and whey	Cause foul odor, pollution, eutrophication	102,975.004
Used washing water	Liquid	Tool washing, Sterilization	Cause foul odor	4,811.610

The waste identification results show that PT XYZ generates two main types of liquid waste: whey, which dominates at 102,975,004 liters, and used washing water amounting to 4,811,610 liters. Both contribute to potential environmental issues such as foul odor, groundwater pollution, and eutrophication. While this identification provides clarity regarding the material balance of production, the company's capacity to manage these wastes remains limited. Human resource constraints are evident, as employees lack specialized knowledge in bioprocessing and waste valorization, making it difficult to convert whey into higher-value products such as fertilizers or animal feed. Capital limitations further restrict the company's ability to invest in advanced wastewater treatment or circular processing technologies, leaving disposal as the only viable option. At the same time, regulatory frameworks emphasize compliance with waste disposal standards but do not provide strong incentives or subsidies to encourage small and medium-sized enterprises (SMEs) like PT XYZ to transform their by-products into valuable goods. Consequently, the identification of waste streams highlights not only technical inefficiencies but also the institutional and resource-based constraints that limit sustainable improvements. Then after being identified, continue to look for points that cause a lot of waste from other factors using a fishbone diagram. The following is the fishbone diagram of the cheese making process:

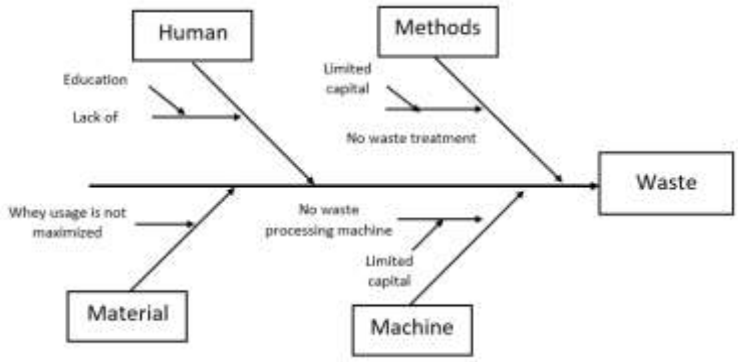

Figure 2. Waste fishbone diagram

Preparation of Non Product Output (NPO)

Here's a concise version that gets straight to the point: The Non-Product Output (NPO) analysis, based on waste identification and fishbone diagrams, measures material and energy inefficiency by identifying inputs not converted into final products.

Table 2. Non Product Output

Process	Cost/input item	Unit	Total input	Unit price (Rp)	Production cost	NPO	% NPO	Total NPO	NPO cost
Milk receipts	Fresh cow milk	liters	112500	Rp 8,000.00	Rp 900,000,000.00	Remaining balance	5%	5625	Rp 45,000,000.00
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		0.75	Rp 10,869.00
Pasteurization	Energy (electricity)	kWh	54	Rp 1,444.70	Rp 78,013.80	Energy (electricity)	10%	5.4	Rp 7,801.38
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		1.5	Rp 21,738.00
Coagulation and Flocculation	Rennet enzyme	gram	2710.858	Rp 4,500.00	Rp 12,198,861.00	Remaining balance	10%	271.0858	Rp 1,219,886.10
	Culture	gram	681.237	Rp 28,000.00	Rp 19,074,636.00	Remaining balance		68.1237	Rp 1,907,463.60
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		1.5	Rp 21,738.00
Separation of curd and whey	Curd	kg	12369.641	Rp 8,500.00	Rp 105,141,948.50	Whey	40%	4947.8564	Rp 42,056,779.40
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		6	Rp 86,952.00
Curd shredding (milling)	Curd	kg	12309.902	Rp 8,500.00	Rp 104,634,167.00	Whey, scattered	5%	615.4951	Rp 5,231,708.35
	Energy (electricity)	kWh	7.2	Rp 1,444.70	Rp 10,401.84	Energy (electricity)		0.36	Rp 520.09
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		0.75	Rp 10,869.00
Salting	Salt	kg	306.089	Rp 10.00	Rp 3,060.89	Curd splatter	2%	6.12178	Rp 61.22
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		0.3	Rp 4,347.60
Pressing	Energy (electricity)	kWh	63	Rp 1,444.70	Rp 91,016.10	Whey	5%	3.15	Rp 4,550.81
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		0.75	Rp 10,869.00
Packaging	Plastic	Unit	4819	Rp 200.00	Rp 963,800.00	Reject	1%	48.19	Rp 9,638.00
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		0.15	Rp 2,173.80
Vacuume sealer	Energy (electricity)	kWh	2.4	Rp 1,444.70	Rp 3,467.28	Energy (electricity)	5%	0.12	Rp 173.36
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		0.75	Rp 10,869.00
Sterilization	Water	liter	2619	Rp 115,740.00	Rp 303,121,060.00	Waste water	20%	523.8	Rp 60,624,612.00
	Energy (electricity)	kWh	6	Rp 1,444.70	Rp 8,668.20	Energy (electricity)		1.2	Rp 1,733.64
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		3	Rp 43,476.00
Aging room	Energy (electricity)	kWh	144	Rp 1,444.70	Rp 208,036.80	Energy (electricity)	10%	14.4	Rp 20,803.68
	Labor	people	15	Rp 14,492.00	Rp 217,380.00	Labor		1.5	Rp 21,738.00
Total Production Cost									Rp 1,447,930,317.41
Total NPO Cost									Rp 156,331,371.03
% NPO Cost									1080%

The NPO analysis reveals a strikingly high cost burden of Rp156,331,371.03, equivalent to 1,080% of production costs, with the largest contributors being whey and water use. While this suggests severe inefficiencies in resource management, these results cannot be separated from the company's broader limitations. A lack of technical awareness among staff often leads to excessive water use in washing and sterilization, inflating hidden costs that remain unrecognized in daily operations. Capital constraints exacerbate the issue, as the company cannot afford to install closed-loop water systems or equipment for whey valorization. Even if processing technologies were available, limited market demand for cheese by-products such as whey-based beverages or fertilizers undermines incentives for innovation. Thus, the NPO results not only expose inefficiencies in resource conversion but also reflect the structural challenges—limited expertise, insufficient capital, and low market readiness—that prevent PT XYZ from turning waste into economic opportunity.

Productivity Calculation

Here's the concise version: After NPO analysis, productivity calculations assess the company's production level to ensure reusable waste is converted into valuable goods. Using input data (materials, energy, labor) and output data (sales), the price of each component is analyzed to determine monthly productivity values.

Table 3. Input-output price value

Month	Input	Output	Productivity percentage
January	354,081,993.50	748,134,200.00	211%
February	397,610,850.00	841,967,600.00	211%
March	385,040,790.00	820,236,000.00	213%

Calculation of Eco Efficiency Index

Here's the concise version: Following productivity analysis, the environmental impact of cheese production was assessed by calculating the Eco-Efficiency Index (EEI) for January–March 2025. Eco-cost values from the Idemat 2024 database (3,192 euros or Rp60,777.7) were used, with all rupiah-based variables converted to euros from prior productivity data.

$$EEI = \frac{Price-Cost}{Eco\ cost+Cost} \text{........................(1)}$$

Januari EEI value

$$\text{EEI} = \frac{39{,}258.123-16{,}530.537}{3.192+16{,}530.537}$$

= 1.374

February EEI value

$$EEI = \frac{44{,}128.814 - 18{,}790.318}{3.192 + 18{,}790.318}$$

= 1.348

March EEI value

$$EEI = \frac{42{,}989.828 - 18{,}131.502}{3.192 + 18{,}131.502}$$

= 1.371

An environmental impact level of 1.3, indicating a sustainable category. While this reflects low environmental pressure, stagnation suggests limited efforts in waste reduction, energy efficiency, and eco-friendly material use. Sustainability requires ongoing innovation, yet the company lacks the expertise to process waste into new products, relying instead on disposal that avoids environmental harm.

Formulation of Alternative Solutions

After evaluating productivity and eco-efficiency, two alternative solutions were formulated to address PT XYZ's waste problem while improving competitiveness. Both options focus on whey valorization, but differ in terms of technological complexity, capital requirements, and market feasibility.

The first option is to process whey into flavored beverages, capitalizing on its high protein and lactose content. However, this option demands new machinery such as pasteurizers, homogenizers, and bottling lines, as well as R&D capacity to develop palatable flavors and ensure food safety standards (e.g., BPOM certification). PT XYZ also lacks marketing expertise and established distribution channels for ready-to-drink functional beverages, which makes this option risky in the short term despite its high value-added potential.

Table 4. Flavored beverages

Variable	Description	Unit	Expenditure for 1 Month		
			Quantity	Price (Rp)	Total Price (Rp)
Material	Whey	Liter	35,540	-	-
	Honey	Kg	1,700	Rp 30,000	Rp 51,000,000
	Fruit flavor	Liter	355	Rp 100,000	Rp 35,500,000
	Citric Acid	Liter	71	Rp 25,000	Rp 1,775,000
	Water	Liter	3,500	Rp 1,100	Rp 3,850,000
Tools	Stainless steel tank (1000L)	Pcs	5	Rp 5,000,000	Rp 25,000,000
	Pasteurizers	Pcs	5	Rp 25,000,000	Rp 125,000,000
	Cooling Jacket Tank	Pcs	5	Rp 15,000,000	Rp 75,000,000
	Industrial Homogenizer	Pcs	1	Rp 15,000,000	Rp 15,000,000
	pH meter	pcs	5	Rp 200,000	Rp 1,000,000
	Digital thermometer	pcs	5	Rp 200,000	Rp 1,000,000
	Activated carbon filter	set	5	Rp 250,000	Rp 1,250,000
	Filling & sealing machine	pcs	1	Rp 40,000,000	Rp 40,000,000
	Cold Storage	pcs	2	Rp 15,000,000	Rp 30,000,000
	250ml Bottle	pcs	164,664	Rp 2,750	Rp 452,826,000
	Labels	pcs	150,000	Rp 1,000	Rp 150,000,000
Others	Advertisement	-	2,000,000	Rp 2,000,000	Rp 2,000,000
Total Input					**Rp 1,010,201,000**
Product Output	Product output	pcs	164,664	22,000	Rp 3,622,608,000
Total Output					**Rp 3,622,608,000**
Profit					**Rp 2,612,407,000**

The second option is to convert whey into organic liquid fertilizer. This solution is technically simpler, requiring only sedimentation tanks, filtration equipment, and mixing containers for nutrient fortification. The process can be operated with the company's existing labor force after short technical training, making it more feasible given PT XYZ's human resource and capital limitations. The regulatory barriers are also lower, as organic fertilizer falls under agricultural product standards that are less stringent than food and beverage certification. Moreover, demand for organic fertilizers in local agricultural markets is relatively stable, supported by government programs encouraging sustainable farming. This makes fertilizer production not only a waste management strategy but also an opportunity to diversify revenue streams at low investment risk.

Table 5. Oragnic liquid fertilizer

Variable	Description	Unit	Expenditure for 1 Month		
			Quantity	Price (Rp)	Total Price (Rp)
Material	Whey	Liter	35,540	-	-
	Molasses	Kg	710.8	Rp 7,000	Rp 4,975,600
	EM4	Liter	71	Rp 25,000	Rp 1,775,000
	Water	Liters	7,108	Rp 1,100	Rp 7,818,800
Tools	Bulktainer /tandon box	Pcs	5	Rp 2,200,000	Rp 11,000,000
	Mixer	Pcs	2	Rp 10,000	Rp 20,000
	500ml Bottle	Pcs	86,860	Rp 5,000	Rp 434,298,000
Others	Packaging label	Pcs	86,860	Rp 1,000	Rp 86,859,600
Total Input					**Rp 546,747,000**
Production Output	Product yield	Pcs	86,860	38,000	Rp 3,300,664,800
Total Output					**Rp 3,300,664,800**
Profit					**Rp 2,753,917,800**

Selection of Alternative Solutions

The decision-making process integrated profitability analysis with broader considerations, including human resources, capital requirements, regulatory frameworks, and prevailing market conditions. Quantitative results indicate that converting whey into organic liquid fertilizer yields the highest profit potential, raising productivity to Rp2,753,917,800 while simultaneously eliminating liquid waste disposal costs. This option proved superior in engineering planning as well, showing a dramatic productivity increase from 211% in March to 928% in April, accompanied by a significant improvement in the Eco-Efficiency Index (EEI) from 1.371 to 7.284 (see Table 6).

Table 6. Productivity increase after liquid waste utilization

Variable	Description	Unit	Expenditure for 1 Month		
			Quantity	Price	Total Price
Materials	Milk	Liters	38,250	Rp 8,000.00	Rp 306,000,000.00
	Rennet	Gram	918.453	Rp 4,500.00	Rp 4,133,038.50
	Culture	Gram	229.352	Rp 28,000.00	Rp 6,421,856.00
	Salt	Kg	101.948	Rp 10,000.00	Rp 1,019,480.00
	Water	Liters	873	Rp 1,100.00	Rp 960,300.00
	Plastic	Pcs	500	Rp 300.00	Rp 150,000.00
Energy	Electricity	kWh	4,365.0	Rp 1,444.70	Rp 6,306,115.50
Labor	Labor Salary	People	12	Rp 5,000,000.00	Rp 60,000,000.00
Others	Tool Depreciation	-	-	Rp 50,000.00	Rp 50,000.00
Total Input					**Rp 385,040,790.00**
Output	Product Sales	Kg	4,101.180	Rp 200,000.00	Rp 820,236,000.00
Total Output					**Rp 820,236,000.00**
Profit per month					**Rp 435,195,210.00**
Waste liquid utilization					**Rp 2,753,917,800.00**
Total Profit					**Rp 3,189,113,010.00**

The choice of whey-based fertilizer production is further reinforced by its strategic feasibility. Unlike whey beverages, which require higher capital investment, specialized skills, and more complex licensing processes, fertilizer production is low-cost, manageable with the current workforce after targeted training, and subject to fewer regulatory barriers. These factors make it a more realistic solution under PT XYZ's operational constraints. Additionally, the strategy aligns well with market opportunities, particularly the growing demand from local farmers for affordable organic inputs. By addressing environmental burdens while simultaneously enhancing economic resilience, whey utilization into organic fertilizer supports the company's broader zero-waste vision and strengthens its long-term competitiveness.

DISCUSSION

The productivity of PT XYZ's cheddar cheese production remains stagnant, with no significant gains in output despite consistent capacity. According to Dwimas et al. (2023) and Nasution et al. (2023), productivity reflects the ratio of output to input, and low whey utilization limits output gains. Efficiency, measured through the Non-Product Output (NPO) approach, shows high waste-related costs, indicating suboptimal use of resources (Adam, 2024; Ranto, 2025). While the European dairy industry utilizes 60–70% of whey for derivative products, PT XYZ discards most whey due to low demand (Rofiq et al., 2023). The Eco-Efficiency Index (EEI) exceeds one, indicating sustainability (Hartini & Yulianto, 2020), but stagnant values show no improvement in impact reduction. In line with eco-efficiency principles (Nurhidayanti & Khawari, 2020; Oduro, 2024), potential solutions include processing whey into organic fertilizer or diversifying into whey-based beverages and feed, which could reduce environmental burdens and enhance profitability (Heizer et al., 2023; Safitri et al., 2022).

CONCLUSIONS AND RECOMMENDATIONS

Analysis of productivity, efficiency, and eco-efficiency at PT XYZ shows that productivity remains stagnant due to the inability to process whey into value-added products. Efficiency is low, with high Non-Product Output (NPO) costs—mainly from unused whey and water—while the Eco-Efficiency Index (EEI) exceeds one, indicating sustainability but with no significant improvement in environmental quality. The company's zero-waste vision has yet to be supported by concrete waste and energy optimization strategies. Data integration suggests that processing whey into organic fertilizer and diversifying derivative products could improve both productivity and efficiency under eco-efficiency principles.

The company should prioritize whey utilization into organic fertilizer or functional drinks, upgrade the heating system for energy efficiency, and strengthen partnerships with local farmers for stable milk supply.

FURTHER STUDY

Future research should combine eco-efficiency with Life Cycle Assessment (LCA) and integrated with AI and IoT-based monitoring to enable fully sustainable cheese production at an industrial scale.

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