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STUDY OF ENVIRONMENTAL IMPACT IMPROVEMENT FOR FISH FEED PRODUCTION COMPANIES

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ABSTRACT:
The national fish consumption increases from 2020 to 2021 of 1.10%. The practices of fish feed production have direct environmental impacts related to emissions to air, water, and soil. The fish feed production process is divided into several stages including the intake, fine grinder, mixer, press, post pellet, dryer, cooler, sieveter, bagging off, and boiler. Considering the environmental impacts from fish feed production activities, there is a need for analysis of those impacts using the LCA method. LCA includes four stages: goal and scope definition, LCI, LCIA, and interpretation. This research is limited to the fish feed production process (gate to gate) and is based on the impact category method ReCiPe 2016 (H) with a midpoint characterization factor. Subsequently, determining environmental improvement program recommendations based on LCA study results and the AHP. The results of the LCA analysis on fish feed production indicate that the production of 1 ton of fish pellets generates 13 impact categories using the ReCiPe 2016 (H) midpoint method. The hotspot in the fish feed production process are found in the boiler unit with the global warming impact category (487,5868956 kg CO_2 eq/ Ton of fish pellets) and the WWTP with the freshwater eutrophication impact category (0,0003883 kg P eq/Ton of fish pellets). The global warming impact is influenced by the emission inventory of CO_2, CH_4, and N_2O, while the freshwater eutrophication impact is influenced by the inventory data of COD and BOD_5.

Keywords: LCA, fish feed, ReCiPe 2016

INTRODUCTION

The national consumption of fish has increased in line with population growth. The Ministry of Maritime Affairs and Fisheries recorded a 1.10% increase in national fish consumption from 2020 to 2021 (Li et al., 2022). In 2020, the consumption was 54.56 kg/capita equivalent to whole fresh fish, while in 2021, it reached 55.16 kg/capita equivalent to whole fresh fish. The Ministry of Maritime Affairs and Fisheries targets a fish consumption rate of 62.5 kg/capita equivalent to whole fresh fish by 2024 (C, 2022). The uncontrolled utilization of fisheries potential through unsustainable fishing practices in the long term can threaten the conservation of aquatic resources. Therefore, the increase in fish production is directed towards aquaculture activities (Androva & Harjanto, 2017).

In fish farming activities, fish feed is the largest requirement. This can be seen from the fish feed demand during aquaculture, which can reach around 60-70% of the production costs (Syawal et al., 2020). The production process of fish feed begins with the intake of raw materials, followed by processes such as fine grinding and mixing. Once the ingredients are mixed, they proceed to the pressing and maturation process in the press and post-pellet machines until they form pellets. The pellets are then dried and cooled using a dryer and cooler machine to achieve the appropriate moisture content. Subsequently, the pellets are sieved using a sieve to separate sizes that do not meet the standards. The final stage is bagging off for packaging purposes. Steam is added for the conditioning process, generated from a boiler unit. The wastewater from the processing process will be treated in the company's wastewater treatment plant (WWTP) (Pan et al., 2015).

The production practices of fish feed have direct environmental impacts related to air, water, and soil emissions. Feed production systems contribute up to 64% of the total anthropogenic greenhouse gas (GHG) emissions released into the environment (Snyder et al., 2009). In addition to GHG emissions, emissions from the use of raw materials (nitrate, phosphate, ammonia) and fuel consumption can result in other forms of pollution such as acidification and eutrophication (Noya et al., 2018). Considering the potential impacts of fish feed production, it is necessary to conduct an impact assessment using the Life Cycle Assessment (LCA) method. Life Cycle Assessment (LCA) is a tool used to assess the environmental impacts and resource use throughout the product life cycle, starting from raw material acquisition, production, and waste management (Finnveden et al., 2009). LCA consists of four stages: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and interpretation of data (Rebitzer et al., 2004). The application of LCA in evaluating the environmental impacts of the industry has benefits, as it can help identify opportunities to improve the environmental performance of products at various stages in their life cycle (Azmi et al., 2021). The impact assessment method employed is midpoint, using the ReCiPe 2016 (H) method, with impact categories tailored to the life cycle inventory analysis. The scope of the LCA study to be conducted is gate-to-gate, aiming to determine the environmental impacts and process units that contribute the most significant impact in the existing fish feed production process.

RESEARCH METHODS

The Life Cycle Assessment (LCA) method is a tool used to assess the environmental impacts and resources utilized throughout the life cycle of a product, starting from raw material acquisition, production, and waste management (Finnveden et al., 2009). The application of LCA in evaluating the environmental impact of industries has several benefits, such as assisting in identifying opportunities to improve the environmental performance of products at various stages of their life cycle. LCA results can serve as a reference for decision-making processes and support the implementation of cleaner production activities (Azmi et al., 2021). LCA is divided into four stages, namely:

Goal and Scope Definition

This stage determines the objectives of the LCA study and establishes the boundaries or scope for conducting the LCA. The objectives of LCA should include reasons for conducting the study, the purpose of applying LCA, the target audience receiving the LCA results, and the use of LCA for comparison across various cases (Parameswari et al., 2019). The scope can be divided into four types: cradle to grave, cradle to gate, gate to gate, and cradle to cradle.

Life Cycle Inventory (LCI)

The Life Cycle Inventory (LCI) stage is the second stage of LCA. This stage involves the inventory of input and output data related to the system being studied. The inventory includes data collection and validation necessary to achieve the objectives of the established study (Fikriyyah et al., n.d.). The purpose of the LCI stage is to demonstrate the environmental impacts of each stage of the life cycle (Astuti, 2019).

Life Cycle Impact Assemssment (LCIA)

The objective of this stage is to evaluate the significance of the potential environmental impacts based on the environmental burden measured in the LCI stage (Astuti, 2019). In this stage, the LCI results are grouped into impact categories. The mandatory elements in the LCIA stage, as stated in ISO 14044, are classification and characterization. The classification stage aims to identify and categorize products with potential environmental impacts into appropriate impact categories based on the selected impact assessment method. The characterization stage aims to determine the magnitude of the impacts for each LCI data (life cycle inventory). Additional steps that can be taken to assist in interpreting the results and drawing conclusions from impact assessment include normalization [5,10].

Interpretation of Data

The interpretation stage allows analysts to evaluate the results, draw conclusions, explain the limitations of the study, and provide research recommendations based on the analysis results from the previous three stages (goals and scope, LCI, LCIA). This phase should provide clear and actionable information for decision-making (Shaked et al., 2015).

The impact assessment method used can vary depending on the analysis objectives and context employed. However, in this study, the ReCiPe 2016 (H) impact method will be used, applied through the midpoint approach (ReCiPe midpoint). Several advantages of the ReCiPe method compared to other methods include its broad range of impact categories at the midpoint level, consisting of 18 indicators, and its applicability as a mechanism for evaluating global-scale impacts. The midpoint impact categories encompass 18 indicators, namely global warming, stratospheric ozone depletion, ionizing radiation, fine particulate matter formation, ozone formation-terrestrial ecosystems, ozone formation-human health, terrestrial acidification, freshwater eutrophication, marine eutrophication, human carcinogenic toxicity, human non-carcinogenic toxicity, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, water consumption, land use, mineral resource scarcity, and fossil resource scarcity (Huijbregts et al., 2017).

RESULTS AND DISCUSSION

Goal and Scope Definition

The first stage involves defining the objectives and scope to be analyzed in the research. The objective of this study is to determine the environmental impact of fish feed production by analyzing the inputs and outputs of each production stage. The scope of this study is gate to gate, where the analysis is conducted from the process of raw material intake to the packaging of fish feed products (bagging off). The functional unit used is 1 ton of fish feed production. The data used in the study is from the year 2021, with a time frame of one year, using secondary data obtained and verified by the company, including raw materials, energy consumption, products, emissions, water usage, and wastewater data. Hazardous waste (B3) and non-hazardous solid waste data are not included in the scope of the study. The Life Cycle Assessment (LCA) study was conducted using Microsoft Excel software, and the impact assessment utilized the ReCiPe 2016 (H) midpoint method. Figure 1 represents the scope of the gate to gate system of the fish feed production company.

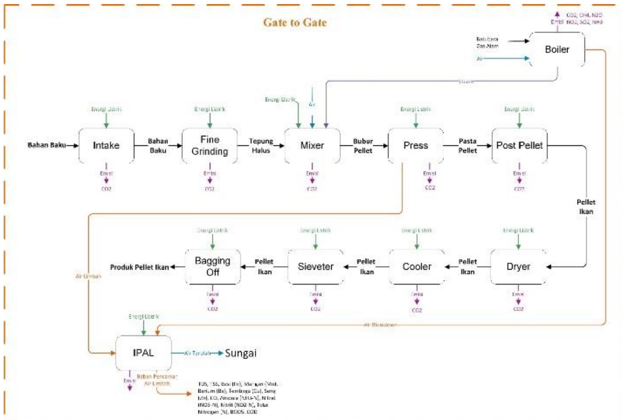

Figure 1. The boundary of the Gate to Gate System for the Fish Feed Production Company

Life Cycle Inventory (LCI)

Life cycle inventory is a quantitative description of material flows, energy, and pollutants within the system boundaries. The data used in the LCA study includes raw material data for fish feed, energy consumption (electricity, coal, and natural gas), fish pellet products, emissions, water consumption for production, and data on the load of wastewater treated by the wastewater treatment plant (WWTP). Data for greenhouse gas (GHG) emissions, namely CO_2, CH4, and N2O, are obtained by converting the use of electricity, coal, and natural gas according to the IPCC 2006 guidelines, as GHG emissions monitoring has not yet been implemented in the company. Laboratory analysis data is obtained from the certificate of test results, which will be used to assist in converting product units to align with the functional unit. The inventory data is then validated through mass balance calculations. The mass balance ensures that the mass input equals the mass output generated at each unit process.

The largest energy consumption is found in the mixer unit (1,493,984.80 kWh), press unit (1,680,732.90 kWh), and post pellet unit (2,054,229.11 kWh). This is because the mixer, press, and post pellet units involve mixing, heating, sterilization, pressure, and maturation of fine flour into fish pellets, requiring more energy compared to other units that only undergo physical processing. Meanwhile, the boiler unit uses energy from coal (2,552.07 tons) and natural gas (32.83 MMSCF) to heat water and generate steam, which is then supplied to the mixer unit. The total water consumption for fish feed processing is 2,959,891.55 m3, obtained from purchasing water from the Gresik Regency's Regional Water Supply Company (PDAM). Wastewater (420.45 tons) is generated in the press unit from the process of pelletizing fish pellets and from the blowdown water from the boiler unit.

Life Cycle Impact Assessment (LCIA)

The life cycle impact assessment (LCIA) stage is the process of assessing the impacts of the obtained inventory data and converting them into potential environmental impacts according to impact categories.

Classification

Impact classification is performed to categorize the inventory data of the fish feed production process according to the impact categories of the ReCiPe 2016 (H) midpoint method.

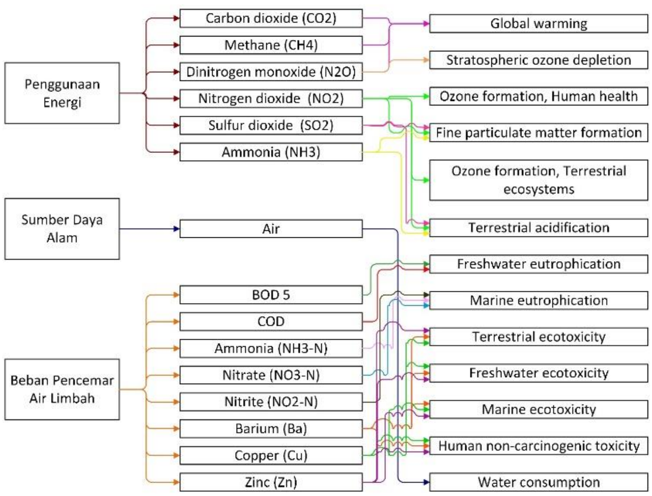

Figure 2. Classification of Fish Feed Production Processes in 2021

In Figure 2, it can be observed that the inventory data of the fish feed company can be classified into impact categories according to the ReCiPe 2016 (H) midpoint method. The energy use results in emissions to the air, including CO_2, CH4, N2O, SO2, NO2, and NH3, which fall under the impact categories of global warming, stratospheric ozone depletion, ozone formation human health, fine particulate matter formation, ozone formation terrestrial ecosystems, and terrestrial acidification. However, the inventory data for the pollutant load of wastewater, such as TDS, TSS, Fe, Mn, CO, and N, do not fall into any impact categories of the ReCiPe 2016 (H) midpoint method as they do not have a characterization factor (CF) value.

Characterization

Characterization is used to magnitudeof substances that contribute to impact categories within the fish feed production process. Impact values are obtained by multiplying the classified inventory data with the characterization factor (CF) in the ReCiPe 2016 (H) midpoint method using Microsoft Excel software.

The calculation equation for characterizing each unit of the fish feed production process, as follows:

$C = Data\ Inventori\ x\ CFm$…………………(1)

Where,

C = Characterization

CFm = Characterization Factor Midpoint

Table 1
The Results of Characterization for Fish Feed Production

Kategori Dampak	Satuan	Total Dampak
Global warming	kg CO2 eq	487,5868956
Stratospheric ozone depletion	kg CFC11 eq	0,0000287
Ionizing radiation	kBq Co-60 eq	-
Ozone formation, Human health	kg NOx eq	0,0103192
Fine particulate matter formation	kg PM2.5 eq	0,0014305
Ozone formation, Terrestrial ecosystem	kg NOx eq	0,0103192
Terrestrial acidification	kg SO2 eq	0,0047854
Freshwater eutrophication	kg P eq	0,0003883
Marine eutrophication	kg N eq	0,0000115
Terrestrial ecotoxicity	kg 1,4-DCB	0,0000000000000000004
Freshwater ecotoxicity	kg 1,4-DCB	0,0066073
Marine ecotoxicity	kg 1,4-DCB	0,0091854
Human carcinogenic toxicity	kg 1,4-DCB	-
Human non-carcinogenic toxicity	kg 1,4-DCB	0,2268948
Land use	m2a crop eq	-
Mineral resource scarcity	kg Cu eq	-
Fossil resource scarcity	kg oil eq	-
Water consumption	m3	102,0233964

Based on Table 1, the production of 1 ton of fish feed results in 13 impact categories. The impacts include 487.5868956 kg CO_2 eq/Ton of fish feed for global warming, 0.0000287 kg CFC11 eq/Ton of fish feed for stratospheric ozone depletion, 0.0103192 kg NOx eq/Ton of fish feed for ozone formation, human health, 0.0014305 kg PM2.5 eq/Ton of fish feed for fine particulate matter formation, 0.0103192 kg NOx eq/Ton of fish feed for ozone formation, terrestrial ecosystems, 0.0047854 kg SO2 eq/Ton of fish feed for terrestrial acidification, 0.0003883 kg P eq/Ton of fish feed for freshwater eutrophication, 0.0000115 kg N eq/Ton of fish feed for marine eutrophication, 0.0000000000000000004 kg 1,4-DCB/Ton of fish feed for terrestrial ecotoxicity, 0.0066073 kg 1,4-DCB/Ton of fish feed for freshwater ecotoxicity, 0.0091854 kg 1,4-DCB/Ton of fish feed for marine ecotoxicity, 0.2268948 kg 1,4-DCB/Ton of fish feed for human non-carcinogenic toxicity, and 102.0233964 m3/Ton of fish feed for water consumption.

Normalization

Normalization is an optional stage in the analysis that aims to standardize units, enabling the comparison of impact magnitudes between different impact categories. The normalization equation for each unit process in fish feed production is as follows:

$$N = \frac{C}{NF} \text{......................................(2)}$$

Where,

N = Normalization

C = Characterization

NF = Normalization Factor

Table 2
The Results of Normalization for Fish Feed Production

Kategori Dampak	Total Normalisasi tiap Dampak
Global warming	0,061022
Stratospheric ozone depletion	0,000479
Ionizing radiation	-
Ozone formation, Human health	0,000502
Fine particulate matter formation	0,000056
Ozone formation, Terrestrial ecosystems	0,000581
Terrestrial acidification	0,000117
Freshwater eutrophication	0,000598
Marine eutrophication	0,000002
Terrestrial ecotoxicity	0,0000000000000000000000027
Freshwater ecotoxicity	0,000262
Marine ecotoxicity	0,000211
Human carcinogenic toxicity	-
Human non-carcinogenic toxicity	0,000007
Land use	-
Mineral resource scarcity	-
Fossil resource scarcity	-
Water consumption	0,382627

Based on Table 2, the impact category with the highest normalization score is water consumption, with a score of 0.382627, followed by global warming with a score of 0.061022, and freshwater eutrophication with a score of 0.000598. The impact category order based on the normalization scores is as follows: ozone formation, terrestrial ecosystems with a score of 0.000581, ozone formation, human health with a score of 0.000502, stratospheric ozone depletion with a score of 0.000479, freshwater ecotoxicity with a score of 0.000262, marine ecotoxicity with a score of 0.000211, terrestrial acidification with a score of 0.000117, fine particulate matter formation with a score of 0.000056, human non-carcinogenic toxicity with a score of 0.000007, marine eutrophication with a score of 0.000002, and terrestrial ecotoxicity with a score of 0.0000000000000000000000027.

Interpretation Data

Interpretation is the final step in the LCA phase where the results from previous stages, including life cycle impact assessment, life cycle inventory, and goal and scope, are connected to draw a conclusion. Problem identification aims to determine the major contributors to the environmental impacts identified through LCI and LCIA analyses using hotspot analysis. Hotspots are the points with the highest impact values within a set of assessed process units. Hotspot analysis aims to identify and prioritize environmental improvement actions based on the locations of the highest potential impacts in the production process of fish feed.

In Table 2, it can be observed that the normalization scores with the highest contributions to the categories of global warming, stratospheric ozone depletion, ozone formation human health, fine particulate matter formation, ozone formation terrestrial ecosystems, terrestrial acidification, and water consumption are located in the boiler unit process. Among the 7 impact categories resulting from the boiler unit process, the greatest contributor to the environmental impact of fish feed production is the global warming impact caused by CO_2, CH_4, and N_2O emissions, as well as the water consumption impact resulting from the use of water from the local water utility (PDAM) for the production process. On the other hand, the categories of freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, and human non-carcinogenic toxicity are associated with the wastewater treatment plant (WWTP) unit process. Among the 6 impact categories that can be generated from the WWTP unit process, the greatest contributor to the environmental impact of fish feed production is the freshwater eutrophication impact.

Based on the conducted analysis, the hotspots for 1 ton of fish feed production are identified in 2 unit processes, namely the Boiler unit with the category of Global Warming impact and the WWTP unit with the category of Freshwater Eutrophication impact. This is based on the highest impact values within the analyzed set of process units and the different impact categories generated by the boiler unit (air emission impact category) and WWTP unit (wastewater impact category). Therefore, to mitigate the impacts caused by the fish feed production process, 2 hotspots are identified.

CONCLUSION

The conclusion of the life cycle assessment (LCA) study on the fish feed production process is that each production of 1 ton of fish pellets will result in 13 impact categories out of a total of 18 midpoint impact categories in the ReCiPe 2016 (H) method. The unit processes and environmental impact categories that contribute the most to the environmental impact of fish feed production are located in 2 unit processes, namely the boiler unit with the global warming impact category, characterized by a magnitude of

487.5868956 kg CO_2 eq/ton of fish pellets, and the wastewater treatment plant (WWTP) unit with the freshwater eutrophication impact category, characterized by 0.0003883 kg P eq/ton of fish pellets.

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