Environmental Impact Reduction in Broiler Chicken Farm Using Life Cycle Assessment in The Implementation of Circular Economy

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Abstract

Chicken manure waste resulting from the process of raising broiler chickens has an impact on the surrounding community and employees. Using Life Cycle Assessment (LCA), an analysis of the existing chicken breeding process with the scope of gate to gate is carried out. There are two outputs of chicken cultivation results, namely broiler chickens and non-product in the form of chicken droppings. Based on processing using SimaPro v.9 software with IMPACT 2002+ method, the output of chicken manure has the most impact on the environment. The biggest impact produced in the form of human health. Through the analysis of the problems, recommendations are given for improvement using a sensitivity analysis approach to reduce the impact of chicken farming output. From this research we obtained that substituting soybean meal into fish meal and raising 20% as a food raw material are alternatives that can reduce the environmental impact. Recommendations for processing chicken manure can use circular economy principles i.e. recycle by processing chicken manure into fertilizer. Some other alternatives can sell chicken manure directly to the fertilizer industry distributor.

Keywords
Life Cycle Assessment, Broiler Chicken Farm, IMPACT2002+, and Circular Economy.

1. Introduction
Broilers are superior breeds resulting from crossing of several types of chickens that have high productivity, especially in producing chicken meat (Nuharja et al. 2018). Indonesia, especially in the field of broiler agroindustry. Statistics show that the number of broilers in Indonesia in 2013 was around 1.3 billion (*Katalog BPS* 2015). The livestock sector contributes to the livelihoods of millions of people, but its production raises several environmental challenges such as greenhouse gas emissions, eutrophication, acidification and biodiversity loss (*Katalog BPS* 2015).

According to attachment I of the regulation of the Minister of Agriculture of the Republic of Indonesia number 31 regarding guidelines for good broiler farming chapter IV concerning environmental preservation to treat livestock waste (Kementerian Pertanian Republik Indonesia 2014). One aspect that has a high enough impact on the environment is the waste from the livestock industry. Livestock wastes contain hazardous chemicals such as NH3, which cause negative impacts on the environment.

Broiler chicken production starts from the maintenance of chicken seedlings. Chicken maintenance consisting of stages of feeding, vaccines, until the chicken is ready to be slaughtered, chicken maintenance takes approximately 40 days. To obtain optimal quality broiler chickens, the cages are cleaned and sterilized after the chickens are ready to be sent to the Chicken Slaughterhouse. The contents of broiler chicken feed are ingredients that are rich in protein, for example: soy flour, turnip flour, fish meal, meat and bone flour, dried distillers grains with solution (DDGS, corn flour from ethanol production), minerals, for example: flour bone, calcium phosphate, calcium carbonate (N. Metal and N. Science 2017). Manure produced from the broiler chicken cultivation process is approximately 113 tons.

Waste generated from chicken farming business includes chicken manure, chicken carcasses and liquid waste. Liquid waste originating from wastewater from the washing place for feed and drinking poultry and other domestic needs. The amount of wastewater is small and is usually absorbed into the soil and has no major effect on the surrounding

environment. Wastewater has a neutral pH value (+7), low organic compound content indicated by the value of Bio Oxygen Demand (BOD) 15.32 - 68.8 and Chemical Oxygen Demand (COD) 35.12 - 92.12 (Andara *et al*. 2014). Chicken manure consists of leftover food and cellulose fibre that is undigested and contains protein, carbohydrates, fats, and other organic compounds. Protein in chicken manure is a source of nitrogen in addition to other forms of inorganic nitrogen. The composition of chicken manure varies greatly depending on the type of chicken, age, individual state of the chicken, and food. Ammonia, dimethylamine (DMA), trimethylamine (TMA), indole, phenol and butyric acid are the most common compounds found in poultry droppings (Nowak *et al*. 2017). Smelling compounds with long-term exposure can cause irritation of mucous membranes in the respiratory tract, irritation of the trachea, inflammation of the air sacs, conjunctivitis, dyspnoea, damage to the respiratory tract, blushing, corneal wrinkles, reduction in respiratory rate, and central nervous system disorders.

This research aims are to identify and evaluate environmental impacts during the life cycle of broiler chickens through a gate-to-gate perspective, from DOC farms to chickens ready to be sent to chicken slaughterhouses. By this evaluation, it can be determined the steps that can be used to minimize environmental impacts.

2. Literature Review

Several methodologies have been applied for the environmental impact assessment of livestock production systems. Life Cycle Assessment (LCA) is the most universal method for evaluating environmental impacts that overcome many of the limitations of other similar methods. Life cycle assessment is used as a tool to assess the environmental impact of the life cycle of a product and activities that are in the process, starting from taking / extracting raw materials, production processes, transportation, use, and destruction. LCA has also begun to be used as a tool for product comparisons, for example comparing environmental impacts based on product use (disposable and repeatedly). At present, LCA has begun to be applied to government policy, marketing, strategic planning, process improvement and product design and improvement.

For LCA, several phases are carried out to identify the categories of environmental impacts of the product life cycle, including the determination of objectives and scope, inventory analysis, environmental impact assessment, and interpretation of results (Clark 2016). Figure 1 is a life cycle phase assessment, while Figure 2 is a scheme of LCA scope.

The scope of the LCA can be broadly divided into four types (Marzuki *et al*. 2013):

- *Gate to gate*, the scope of the study is limited to the nearest process activity.
- *Cradle to gate*, the scope of the study ranging from raw materials to activities before the production process.
- *Cradle to grave*, the scope of the study ranging from raw materials to the finished product in production.
- *Cradle to cradle*, the scope of the study ranging from raw materials to materials recycled.

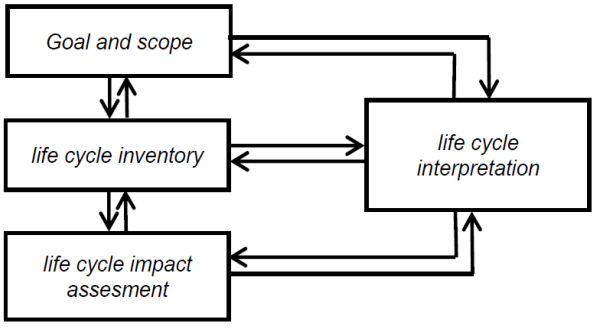

Figure 1. Life Cycle Assessment phase.

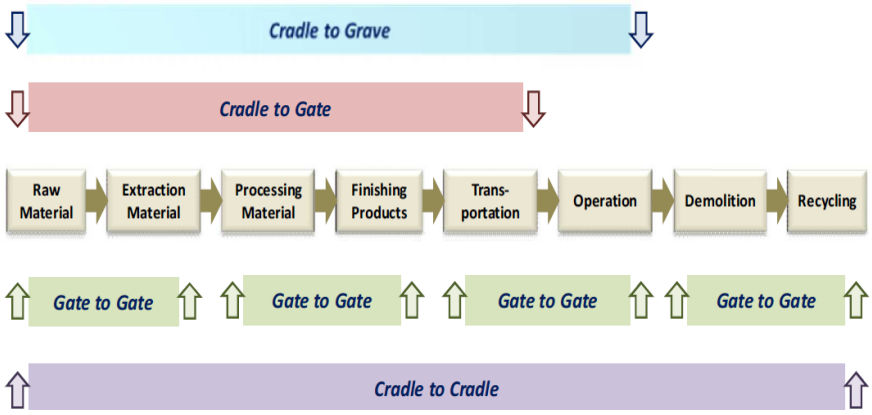

Figure 2. LCA scope.

LCA is a holistic method and is suitable for assessing the environmental impact of a product throughout its life cycle (Bartzas *et al*. 2015). The LCA was originally developed to assess the environmental impact of production and industrial processes, then was applied to livestock production systems. Several studies have used LCA to evaluate the environmental impact of various types of livestock (Pelletier 2008).

The scope of LCA consists of cradle to grave, cradle to gate, gate to gate, and gate to grave. In this study, the scope used is gate to gate. In this scope, the use and disposal phases of the product are eliminated. Gate to gate was chosen because based on available facts, the environmental impact contained around the company is waste generated from the company's internal activities, especially in the chicken farm. LCA studies on broiler chicken farms contribute greatly to the environmental impact. In other words, the environmental burden of meat is mainly caused by the livestock system. Pig and poultry farms produce lower emissions than cattle, sheep and dairy farming.

Circular Economy (CE) is an alternative industrial model where by taking a holistic and systemic approach, industrial processes are not seen as an inevitable cause of exploitation of natural resources, environmental pollution, and waste generation, but rather as a means to contribute to sustainable development (Tonelli and Cristoni 2018). Today many companies are required to treat their production waste. Circular Economy relies heavily on the 3R principle: Reduce, Reuse and Recycle. The principle of circular economy is one alternative that can be applied in waste treatment. In the chicken farm sector, an example of a principle that can be used as a reference for treating waste is the recycle principle. Focusing on the company's ability to regulate the flow of material and circular products. The recycle principle can be applied as a consideration of recommendations to reduce the environmental impact on broiler farms. The main purpose of a circular economy is to design waste and maximize the (re) utilization of raw materials and products that would otherwise be quickly discarded, not used, or considered using (Weetman 2017).

3. Methods

This study uses LCA to compare the full range of environmental effects assignable to products (in the case of this study broiler) by quantifying all inputs and outputs of material flows and assessing how these material flows may affect to the environment. LCA consists of four main phases: goal and scope; life cycle inventory; life cycle impact assessment; and interpretation.

3.1. Data Collection

The data collection process was carried out in the Pratiwi farm. Data collection is done after identifying the data needed for research. Data sources consist of primary data and secondary data. Primary data were obtained directly from Pratiwi Farm, Boja by directly observing the process of broiler chicken farming and holding discussions with employees and owners of the farm. While secondary data obtained from national and international journals and research reports are still relevant, both about broiler chicken farms and about the Life Cycle Assessment.

3.2. Data Processing

Life Cycle Assessment (LCA) is used to analyse the production process of broiler chickens. From the results of data processing using Life Cycle Assessment (LCA), the part of the process that will give the greatest environmental impact will be identified, so that recommendations will be chosen based on the results of the LCA.

In the LCA calculation, SimaPro Software will be used to process the data that has been obtained to analyse its relationship with ecological aspects. There are four phases to be passed in the LCA calculation:

1. *Goal and Scope Definition*

This phase aims to formulate and describe the objectives, the system to be evaluated, the limits, and assumptions related to impacts throughout the life cycle of the system being evaluated for broiler chicken farms. The purpose of this study is to analysis and compare the amount of environmental impact arising from the production process of broiler chickens at the stage of raising chickens based on the Life Cycle Assessment approach. While the scope used in this study is "gate to gate" which includes a series of broiler chicken farming processes.

2. *Life Cycle Inventory* (LCI)

At this stage data was collected in the form of chemicals used in the process of broiler chicken farming, energy, and transportation used in the livestock process. The input of raw materials, energy and transportation will be adjusted to the SimaPro database. The data entered in the SimaPro software was determined based on the description of the observation system.

3. *Life Cycle Impact Assessment* (LCIA)

Life cycle impact assessment calculation using SimaPro v.9 software with IMPACT 2002+ method. The IMPACT 2002+ impact assessment methodology is strongly based on preliminary results from the LCIA definition study (life cycle impact assessment) of the SETAC-UNEP Life Cycle Initiative (Hischier *et al*. 2010). This methodology is based on the LCIA approach which was midpoint oriented and damage oriented.

4. *Interpretation Step*

Provides results in the form of diagrams that show the significance of the results of the impact categories so that from the diagram we can know the biggest impact categories.

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4. Result and Discussion

This study aims to identify and evaluate environmental impacts during the life cycle of broiler chickens through a gate-to-gate perspective, from DOC farms to chickens ready to be sent to chicken slaughterhouses. By this evaluation, it can be determined the steps that can be used to minimize these impacts.

This first phase also determines the limits of the system under study so that the scope of the study is clear. The limitation is regarding the functional unit. In this study, the function unit was 1 kg chicken weight.

Life Cycle Inventory (LCI) shows inputs (the amount of chicken raw material and other supporting components) and outputs (for example: by-products, waste, emissions etc.) associated with the product throughout the specified production cycle. The structural unit used in the study is 1 kg chicken weight. A Life Cycle Inventory was showed in Table 1 and Table 2.

LCI input consists of DOC and supporting material. In the cultivation of broiler chicken, the raw materials needed are the amount of feed needed for 1 kg of broiler chickens in accordance with the functional unit of 1.8 kg consisting of maize of 0.72 kg, soybean meal of 0.54 kg, meat and bone meal of 0,18 kg, and maize grain 0.36 kg. Water requirement needs as much as 1.82 litres for 1 kg of broiler chickens. The amount of electricity is 0.004 kWh. Table 2 displays the Life Cycle Inventory output. Output is divided into 2 namely product output and non-product output. The product output is broiler chicken weighing 2.5 kg while the non-product output is solid waste (chicken manure). The amount of nitrogen produced from chicken manure is 0.053 kg. Chicken manure produces ammonia emissions of 0.013 kg, which is obtained from the percentage of the amount of nitrogen produced by broiler chicken phases.

Table 1. LCI input.

Input	Amount	Unit		Source
Material	0.72	kg	*Maize*	Company data
	0.54	kg	*Soybean Meal*	Company data
	0.18	kg	*Meat bone meal*	Company data
	0.36	kg	*Maize grain*	Company data
	1.82	liter	Water	Company data
Electricity	0.0047	kwh	Electricity need to chicken farming cover	Measurement on the object
DOC	45	g	Chicken	Company data
Nitrogen	11.14	%	% the total amount of chicken manure	Laboratory test

Table 2. LCI output.

Outputs		Amount	Unit	Source
Product Output (PO)	Broiler	2.5	Kg	Company data
Output	Manure	0.48	Kg	Measurement on the object
Emission	Ammonia	25	% total amount of nitrogen in chicken manure	(US EPA 2020)

In this phase using SimaPro v.9 software with IMPACT 2002+ 2019 version 2.1 where IMPACT 2002+ values and indicators are based on standards created based on a combination of IMPACT 2002, Eco-Indicator 99, CML, and IPCC methods.

Single score is a step that aims to classify the value of impact categories based on activities or processes. From the value of a single score can be seen activities that contribute to environmental impacts and damage impacts. Table 3 shows the single score of the environmental impact of raising broiler chickens.

In this study the single score is stated in the amount of Pt. Table 6 showed that the largest value generated is in the category of human health impact for chicken manure by 1.3 mPt and for broiler chickens by 0.79 mPt.

Table 3. SimaPro single score output.

Damage category	Unit	Total	Broiler	Manure
Total	**mPt**	**5.80750346**	**2.57509309**	**3.23241037**
Human health	**mPt**	**2.01885233**	**0.70929734**	**1.3552028**
Ecosystem quality	**mPt**	**2.65334597**	**1.29814317**	**1.30955499**
Climate change	**mPt**	**0.86984112**	**0.43492056**	**0.43492056**
Resources	**mPt**	**0.26546404**	**0.13273202**	**0.13273202**

Human health in the IMPACT 2002+ method consists of several mid points, namely human toxicity, respiratory effects, ionizing radiation, ozone layer depletion, and photochemical oxidation. In this study, human health is caused by the ammonia gas content that is formed due to the process of raising broiler chickens. Ammonia gas content is a result of decomposition of nitrogenous waste material in excreta, such as uric acid, protein that is not absorbed, amino acids and other non-protein nitrogen (NPN) compounds due to microorganism activity in faeces (Riza *et al*. 2015). Figure 3 is a comparison picture of each impact category produced by the chicken farming process output.

The influence of chicken feed composition causes the greatest impact on the environment, hence chicken feed is considered the most sensitive. The composition that contributed highly to the environmental impact was soybean meal by 27.2%. The use of alternative ingredients for animal feed can improve the environmental performance of the production process, such as the use of special ingredients (Lima *et al*. 2019). If the soybean meal is substituted with fish meal ingredients and the composition increases by 20%, the performance results obtained are as follows. Table 4 summarizes the results of environmental impact values after the sensitivity analysis has been carried out.

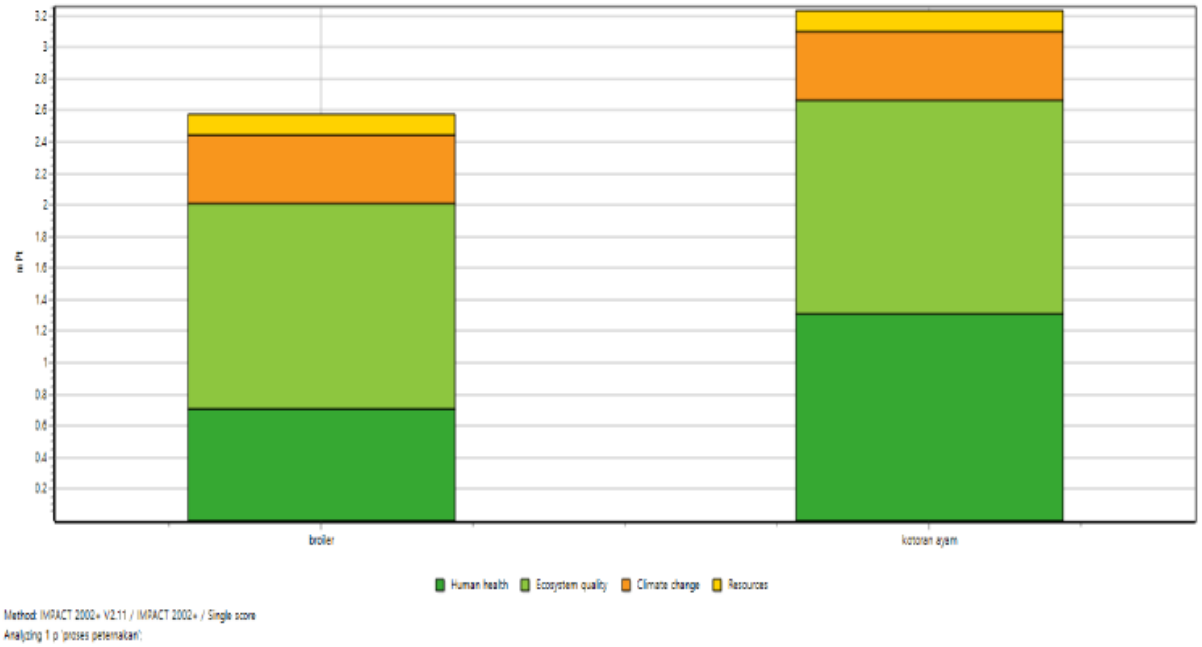

Figure 4. SimaPro software output impact of broiler chicken farming.

Table 4. SimaPro software output calculation single score sensitivity.

Damage category	Unit	Total	Broiler	Manure
Total	mPt	3.79526976	1.80561046	1.9896593
Human health	mPt	1.46945511	0.65069148	0.81876363
Ecosystem quality	mPt	1.39084265	0.68743298	0.70340967
Climate change	mPt	0.54273201	0.27136601	0.27136601
Resources	mPt	0.39223999	0.19612	0.19612

Based on the Table 4, the composition of soybean meal was replaced by the composition of fish meal and increased by 20% then there was a change in the impact of broiler chicken cultivation. The results are the category of human health effects caused by broiler chickens decreased by a difference of 0.05, while the category of human health impacts caused by chicken droppings decreased by a difference of 0.1. Ecosystem quality impact categories for broiler chicken output decreased by 0.51 and chicken manure decreased by 0.556, climate change impact categories decreased by 0.16. While the resource impact category increased by 0.06. This is due to an increase in the midpoint category for non-renewable energy and mineral extraction. Based on the sensitivity analysis, it can be concluded that by replacing the

composition of soybean meal into fish meal, it can reduce the environmental impact caused by the broiler chicken breeding process. Table 4 shows the calculation of SimaPro Software output.

Chicken manure waste treatment is carried out to reduce the impact caused by the process of raising broiler chickens. In the waste collection applied by Pratiwi Farm, it is by piling up waste beside the farm. New opportunities for circular economy are created by the utilization of waste biomass, such as post extraction residues rich in micronutrient ions, such as Cu, Mn, and Zn ions to produce bio-based micronutrient fertilizers (Chojnacka *et al*. 2020).

The application of animal manure on agricultural land as organic fertilizer to replace mineral fertilizer has been considered, taking into account the avoidance of mineral fertilizer production. The use of chicken manure as raw material for fertilizer has been widely applied in several farms. Chicken manure waste, which is dumped beside the farm, can be reduced by processing its own waste into fertilizer or it can also be sold at several fertilizer processing distributors. If chicken manure waste is processed into fertilizer by the owner requires investment of several tools, but the economic value will be higher than chicken manure directly sold to distributors. Compost treatment from waste is an innovation, in addition to increasing creativity and economy, it also can reduce the impact on the environment.

5. Conclusion

The broiler chicken farm process produces four categories of damage impacts, namely human health, ecosystem quality, climate change and resources. The biggest environmental impact is human health. The cause of damage to the human health category was caused by the ammonia content generated from the waste of chicken manure produced. These chemical compounds contribute to the decline in the quality of ecosystems and public health.

The most possible alternative to reduce the impact on the ecosystem from chicken farming waste is to replace the composition of chicken feed from soybean meal into fish meal. Another alternative to reduce the environmental impact can also be done by using chicken manure waste as fertilizer, besides that waste can also be minimized by selling chicken manure.

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