International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 27 No. 2 July 2021, pp. 489-498

The Impact of Global Warming Potential on Pasteurized Goat Milk Production (Case Study from Rantiang Ameh Ranch, Agam Regency, West Sumatra)

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Abstract – The livestock sector is responsible for 14% of total Green House Gasses (GHG) (European Commission (EC), 2019). Life cycle Assessment (LCA) method is a mechanism for analyzing and calculate the total environmental impact of a product in each stage of its life cycle. This LCA study was conducted on pasteurized goat milk produced in the Milk Processing Unit (MPU) Rantiang Ameh and is limited in the scope of cradle to gate where analysis of the production process starting from the feeding process (cradle), maintenance, milking, and pasteurized milk processing. Functional unit used is FPCM (Fat Protein Corrected Milk). This research was conducted with 2 scenarios. Scenario 1 is the existing condition in the field where forage feed is taken directly from nature without the planting process and scenario 2 it is assumed that forage feed is planted on the land special. The results of the life cycle inventory analysis of pasteurized goat's milk production in Rantiang Ameh Farm which has been carried out using SimaPro 9.0.0 software with Ecoinvent 3.5 database and baseline CML method on impact analysis, the amount of CO_2 emissions equivalents that have an impact on GWP in one cycle of pasteurized goat milk production in scenario 1 of 3.52 kg CO_2 eq/FPCM Milk and scenario 2 of 4.73 kg CO_2 eq/FPCM milk.

Keywords – ***Goat milk, Global Warming Potential (GWP), Life cycle Assessment (LCA).***

I. INTRODUCTION

The livestock agribusiness sector in Indonesia is growing along with the increasing public awareness of consuming animal industry food. In 2010 Until 2019, cow's milk production in Indonesia increased with an average growth 9.80% per year. In the same year period, cow's milk production outside Java shows an increase in the average annual growth of 2.91%. Production increase Cow's milk has not been able to cover the need for milk consumption in Indonesia, which is marked by: the deficit in the availability of cow's milk reached 42.92 thousand tons in 2019 (Ministry of Agriculture, 2019).

The alternative to meet the needs of milk in Indonesia is by diversification of dairy products, one of which is goat's milk. According to the 2019 Central Statistics Agency (BPS) goat population growth in Indonesia has increased by 18% from 2009 until 2018. Rantiang Ameh Ranch is one of the most popular dairy goat farms located in Agam Regency, Canduang District, Kenagarian Bukik Batabuah. Goat species The milk that is cultivated in this farm is the Etawa Peranakan (PE) goat. The PE goat is a superior goat from Indonesia, the result of a cross between a local peanut goat with Jamnapari goat from India.

Dairy goat farming not only produces solid waste (feces) and liquid (urine) but also a gas. Gas produced from livestock waste can be in the form of nitrogen gas (N2), carbon dioxide (CO2) and methane (CH4). These gases are classified as greenhouse gases. These are gases that trap heat in the atmosphere (U.S.Environmental Protection Agency (EPA)).

According to the European Commission (EC) (2019), the livestock sector is responsible for 14% of total global Greenhouse Gas (GHG) emissions. Livestock sector is estimated produces 5,335 Mt CO2 equivalent per year. And the global dairy sector is estimated contribute 4% of anthropogenic GHG emissions (Gerber et al., 2010). In GHG emission evaluation of the liquid milk supply chain, Thoma et al. (2013) found that 72% of emissions occur in on farm process (process before milk leaves the farm). Livestock production system dairy goats and goat milk processing need to reduce their carbon footprint in an effort to reduce GHG carbon emissions. For this reason, it is necessary to evaluate and analyze the impact environment of each stage of goat milk production.

The LCA method has been widely used for assessing the environmental sustainability of various products. LCA is a mechanism for analyze and calculate the total environmental impact of a product in each stage life cycle, starting from the preparation of raw materials, the production process, sales and transportation, and product disposal. (Hamonangan, S.P, Handayani, N.U and Bakhtiar, A. 2016).

The LCA method consists of four phases, namely the determination of objectives and scope, analysis, inventory, impact analysis, and interpretation (ISO14040:2006). The results of the LCA can be used as considerations for choosing the use of raw materials and processes used so that can reduce the environmental impact caused by the implementation of a production process, LCA is also the basis for decision making by policy makers, producers, and consumers in choosing products and production processes that are sustainable for environment. Therefore, in order to analyze the environmental impacts caused in Rantiang Ameh Ranch, Agam Regency, West Sumatra, it is necessary to know the estimation regarding environmental impacts in the form of GHG emissions or also known as Global Warming Potential (GWP).

LCA research was conducted on pasteurized goat's milk products produced in the Unit Milk Processing (UPS) Rantiang Ameh. According to SNI 01-3951-1995 pasteurized milk is fresh milk, reconstituted milk, recombined milk that has undergone a heating process temperature 63 °C – 66 °C for 30 minutes or on heating 72 °C for 15 seconds, then immediately cooled to 10 °C, then treated aseptically and stored at maximum 4.4 °C (BSN 1995). Pasteurized milk produced from Rantiang Ameh by correcting the percentage of fat and protein. The aim of this research is calculate the amount of CO2 equivalent emissions that impact GWP in one cycle pasteurized goat's milk production

II. METHODOLOGY

The location of the research was carried out at Rantiang Ameh Ranch in Bukik Batabuah, Canduang District, Agam Regency. Data used in this research in the form of primary data and secondary data.

Primary data obtained from direct interviews with onfarm and off farm managers and field observations in Rantiang Ameh.Secondary data obtained from literature studies and grass planting emission data from the Ecoinvent 3.5 database.

The number of goats that are kept as many as 150 heads consisting of 72 female parents, 4 males, 28 damsels, 24 young males and 22 hens, the amount of feed required both forage feed and concentrate feed (tofu dregs), supplements, minerals and given vitamins. Secondary data in the form of goat weight data, data on electricity, water, and the diesel fuel used.

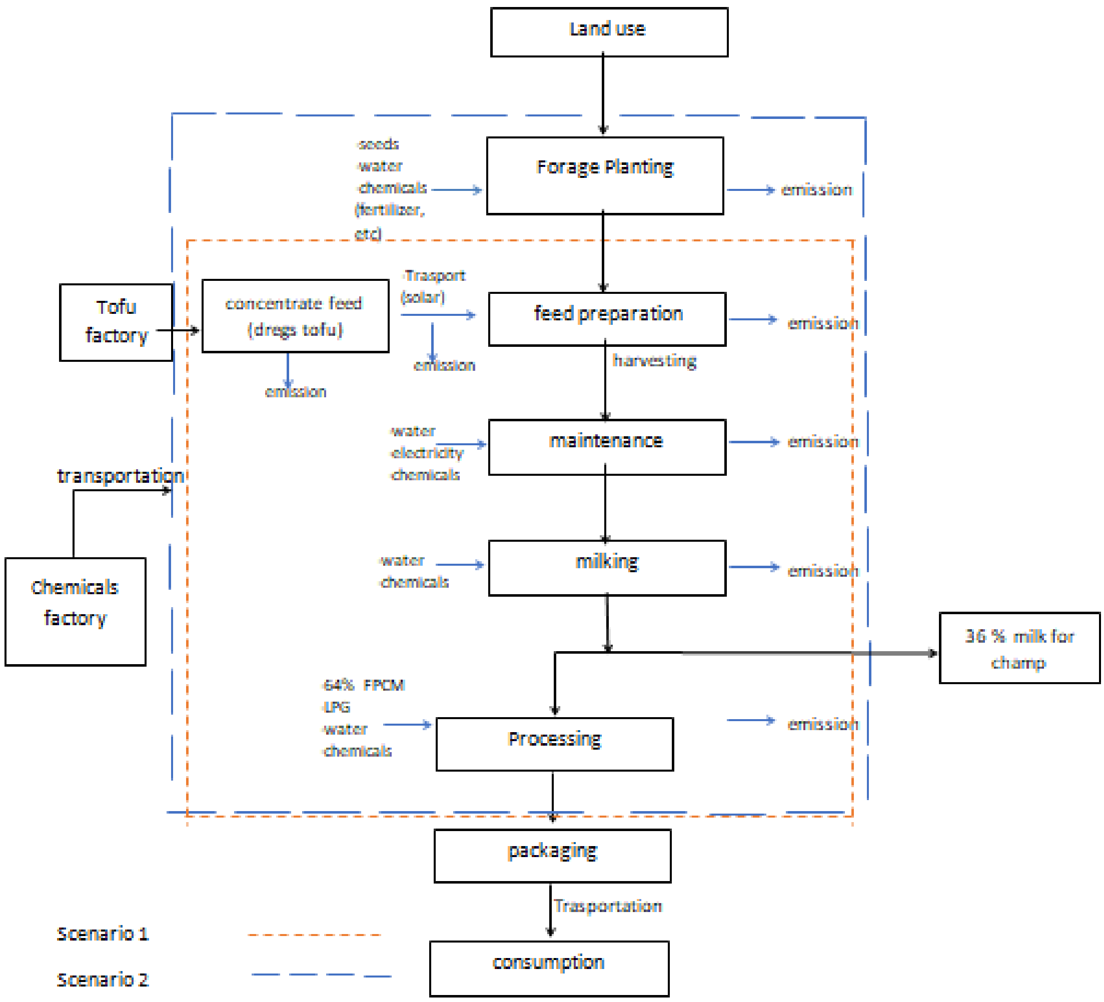

Figure 1. Research Boundary System

Research carried out in four stages of the process, namely in the process of feed preparation, maintenance, milking and processing. This research conducted with 2 scenarios, namely scenario 1 (existing conditions in the field) where forage is taken directly from nature and scenario 2 when forage is planted on special land.

The method used in this study was the calculation of the impact with LCA method. The method LCA consists of four phases, namely the determination of objectives and scope, inventory analysis, impact analysis, and interpretation (ISO14040:2006).

This study is limited in the scope of cradle to gate where the analysis is limited to the production process starting from the feeding process (cradle), maintenance, milking, and the process of pasteurized milk (gate). Functional unit used is FPCM (Fat Protein Corrected Milk), for dairy goat's milk, standard energy content is 0.64 Mcal/kg (Colin Prosser in Robertson et al, 2015). For dairy goats, the standard energy content calculated by the following equation:

$$FPCM(kg) = \text{raw milk (kg)} \times [0.145 \times \text{fat content (\%)} + 0.092 \times \text{protein content (\%)} + 0.3]$$

Inventory Analysis described the flow of matter and energy in activities farm. Some of the data obtained by calculations using Microsoft Excel with equations from IPCC (The Intergovernmental Panel on Climate Change) 2006, and data from previous research. The boundary system in conducting an inventory of input and output data can be seen in figure 1.

Identifying categories of impacts caused by the livestock system is carried out at the beginning of the impact assessment. The category of impacts presented is the impact of warming global warming potential (GWP) expressed in CO2 eq over a 100 year period.

GWP comes from CO2, CH4, and N2O emissions. CO2 emissions are generated indirectly from the use of fuel for transportation, electricity use and the use of fertilizers in feed cultivation.

CH4 emissions come from enteric fermentation, manure management and from the use of fuel for transportation. Meanwhile, N2O emissions come from farm manure management. Carbon dioxide, methane and nitrous oxide are greenhouse gases that provide a green house effect (capable of absorbing diesel oil heat) so that levels are positively correlated with an increase in the earth's temperature or what is known as global warming (GWP).

Analysis of environmental impacts produced by Rantiang Ameh Dairy Goat Farm calculated and carried out data processing using Microsoft Excel and then the data was entered as quantitative inventory data into SimaPro software version 9.0.0 and supported data from the Ecoinvent 3.5 database and the CML method for impact analysis (LCIA).

III. RESULT AND DISCUSSION

In this study, the existing conditions on farms with feed obtained from wild plants are considered as scenario 1 and the assumption is that tithonia and elephant grass are planted or cultivated on special land so that they require fertilizer for maintenance as scenario 2.

The need for feed on this farm in a month reaches 33.75 tons of forage (27 tons of tithonia plants and 6.75 tons of elephant grass), 10.05 tons of concentrate (tofu dregs), supplements (27 kg of minerals, Vitamin B12, B Complex, and Vitamins A, D, E). Concentrated feed in the form of tofu dregs is given mixed with goat minerals and feed water. Feed water in a month is needed about 8100 liters. Water needs at Rantiang Ameh farm are met from ground water using a shimizu PC-268 BIT water pump and accommodated in 2 torens with a capacity of 1000 liters. A water pump with a power of 250 watts is used for approximately 4 hours a day.

In scenario 2, tithonia and elephant grass are planted specifically on the land so they need fertilizer. Tithonia plant or also known as paitan is an annual plant that has the potential as a source of organic matter due to its high biomass productivity, which is around 5.6-8.1 tons/ha/year (Purwani, 2011). If the average productivity of tithonia per year is 6.85 tons/ha, and it is known that this plant is harvested at 8 WST (weeks after planting), then in one year this tithonia plant can be harvested 6.5 times as much as 1, 05 tons/ha/one harvest. Elephant grass with a productivity of 60 tons/ha/ta and can be harvested at the age of 30 days (Purwawangsa, 2014), then in a year elephant grass can be harvested 12 times as much as 5 tons/ha/one harvest. The data for forage planting is inputted into the SimaPro software and from the Ecoinvent 3.5 database, 68,067 kg of grass/ha are generated.

The form of activities in the maintenance system are feeding, cleaning the cage, bathing goats, giving vitamins, weighing goats and checking goat health.

For feeding, it is done 3 times a day, while concentrate feed is only done 2 times, namely in the morning and evening. Cleaning the cage carried out once a day by using a water spray hose, broom, dustpan and other cleaning tools. Cleaning using a disinfectant carried out once a month using acetic acid and detergent. Cleaning goats in the form of bathing the livestock carried out 2 times a month using water and detergent. And the provision of goat vitamins is given once a month in the form of injections of Vitamin B Complex, B 12, and Vitamins A, D, E. While the measurement of goat weight is carried out when the goat will be weaned, enter mating age and when it will be sold. Separation of cages for female, male and female goats as well as for sick goats.

The third system is goat milking. Before milking, the farmer cleans the nipple and the area around the goat's nipple using warm water. In addition, farmers also use iodine as an antiseptic for nipple dipping and alcohol (ethanol) as a hand sanitizer. Next, milking is done manually by hand. The resulting milk is stored in a place that has been cleaned using dishwashing liquid and dried. Next, the milk is filtered using two layers of gauze and put into a milkcan to be brought to the Milk Processing Unit (UPS). After the milking process, wash the nipples with warm water. Milking is done 2 times a day, in the morning at 08.00 and in the afternoon at 16.00.

Milk processing at UPS which is 30 meters from the farm. The transportation of milk from the farm pens to the UPS is done by human power. Processing of milk into pasteurized milk is carried out using the LTLT (Low Temperature Long Time) method. At UPS Rantiang Ameh, milk is heated at a temperature of around 65°C for 30 minutes. Heating is done by using a heat source from LPG. The batch pasteurization pot used has a capacity of 12 liters, and warm water in batches is 5 liters. After heating, the milk is immediately thawed (returned to product temperature) in a thawing bath until the milk temperature is approximately 30°C. After each use, the pasteurized batch pan is washed using dishwashing liquid and clean water and then dried.

Inventory analysis can determine the flow of material and energy required at each stage of the process or system. Inventory data at Rantiang Ameh Ranch per process stage in a month showed in Table 1.

Calculation of indicator results (characterization) involves converting LCI results into common units and grouping the conversion results into the same impact category. This conversion is done by using the characterization factor. The characterization factor characterizes the contribution of the inventory parameters to determine the impact category of these parameters so that impact quantification can be carried out (Lee in Taufiq 2015). The resulting impact value is usually the impact emission factor value multiplied by the inventory value. Generally the emission factor values are contained in the database. The result of the calculation is a numerical indicator. From milk production data from January to March 2021, it was found that the average amount of goat's milk produced at Rantiang Ameh Farm from those three months was 1,116.48 liters. A total of 714.54 liters (64%) were processed at UPS and 401.93 liters (36%) were given to cempe (goat chicks).

A Specific gravity, fat percentage, milk protein percentage were measured using a Lactoscan MCC50 Milk Analyzer. From the measurements from January to March, the average density value was 1025.05 kg/m3, 8.76% fat and 3.86% protein. With these data and formulas, the value of 1 FPCM is 3.08 liters of milk. Based on the reference livestock emission data from the Research and Development Center-SDA, Ministry of Public Works and goat body weight data at Rantiang Ameh farm, the total value of emissions to water is shown in table 2.

Table 1. Inventory Data on Rantiang Ameh Farm for a month

Stages (Data)	Unit	Total	Emission Data Source	
			Scenario 1	Scenario 2
Feed preparation				
- Elephant grass	ton	6,75	database	database
- Tithonia plant	ton	27	database	asumsi& database
- Minerals	kg	27	database	database
- Water	liter	8100	database	database
- Tofu dregs	ton	10,05	literatur	literatur
- Transportation (diesel oil)	liter	120	calculation	calculation
Maintenance				
- Forage	ton	33,75	database literatur	database
- Concentrate feed (Tofu dregs)	ton	10,05	database	literatur
- Water	liter	8100	database	database
- Water for cage	liter	30.000	database	database
- electricity	kWh	30	database	database
- CH_3COOH	ml	150	database	database

- Detergent	kg	7.550	calculation	database
- Solid waste	kg	2.700	calculation	calculation
- Liquid waste	liter	4.500	calculation	calculation
- Gas waste	kg CH_4	6,5E-5	calculation	calculation
	kg N_2O	3,98		calculation
Milking				
- Etanol	liter	1,8	database	database
- Warm water	liter	300	database	database
- Iodium	liter	1,8	database	database
- Dishwashing liquid	ml	180	database	database
Processing				
- LPG	kg	10,4	database	database
- Water for pasteurisasi	liter	300	database	database
- Dishwashing liquid	ml	180	database	database
- Goat Milk	ml	714,54	calculation	calculation

Table 2. Total Emissions of Goats to water

Parameters	Emission Factor (mg/kg body weight/day)	Total (kg/month)
BOD_5	142	25,09
COD	319	56,37
NO_2	0,011	0,002
NO_3	0,31	0,055
NH_4	6,12	1,081
N total	6,56	1,159
P total	0,48	0,085

Source: Livestock Emissions Reference from Research and Development Center for Natural Resources, Ministry of Public Works & Excel processed data

The value of emissions to water resulting from the calculation of Table 2. inputted into the SimaPro software as an inventory of the value of emissions to water. Emissions to air are calculated from enteric fermentation emissions and manure management emissions, and emissions to soil are calculated from manure management livestock, where 60% of unsold manure is dry lots. The results of the calculation of emissions to the air using the IPCC 2006 equation from enteric fermentation of 6.25E-5 kg CH4/month and from manure management of 2.75E-6 kg CH4/month and 3.98 kg N2O/month. The electricity in the feed system is used to power the water pump. The water pump in a day runs for 4 hours to meet the water needs of the farm. Fuel in the form of diesel fuel is spent 4 liters a day for transporting feed in the form of forage feed from the area around the Candung District to the cage, and concentrate feed (tofu dregs) from the tofu factory in Ampek Angkek District to the cage. In scenario 2, tithonia and elephant grass were planted. In the Ecoinvent 3.5 database there is no inventory of tithonia plants, only elephant grass inventory is available, so it is assumed that tithonia plants are the same as elephant grass. The output of this grass planting is 68,073 kg/ha of grass (Ecoinvent 3.5 Database), which will be input to the maintenance system. Emissions resulting from the feed preparation system in the form of using 120 liters of diesel fuel for feed transportation calculated based on the IPCC 2006 in a month are 320.11 kg CO2/month, 16.85 x 10-3 kg CH4/month and 16.85 x 10-3 kg N2O/month. And other emissions from tofu waste are 1.96 x 10-2 kg CO2/month (Mejia et al. 2017). The emission values generated from the above calculations are inputted into the SimaPro software as quantitative inventory data which will be completed from the Ecoinvent 3.5 database to calculate the resulting GWP impact. The magnitude of the impact of GWP in kg CO2 eq/FPCM of milk per process stage showed in Table 3.

Table 3. Impact of GWP (kg CO2 eq/FPCM Milk) per process stage

Scenario	Feed preparation	Maintenance	Milking	Processing	Total
1	0,292	3,18	0,0108	0,0364	3,52
2	1,5	3,18	0,0108	0,0364	4,73

The comparison of the impact of GWP in scenario 1 and scenario 2 is shown in Figure 2.

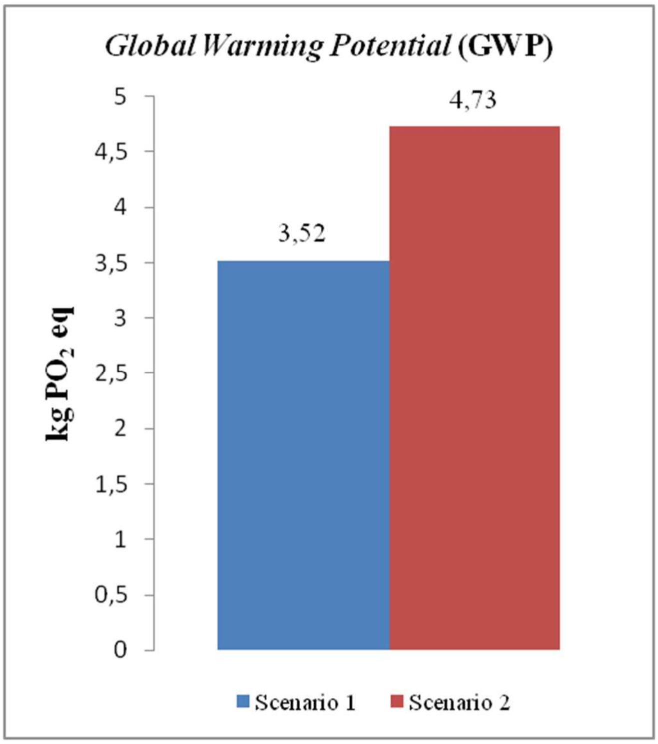

Figure 2. Comparison of the GWP

Impact of the two overall scenarios Figure 2 shows the comparison of the GWP impact of the two overall scenarios. The GWP impact shown in equivalent CO2 is greatest in scenario 2, which is 4.73 kg CO2 eq/ FPCM of goat milk, while in scenario 1 the CO2 emission produced is 3.52 kg CO2 eq/ FPCM of goat's milk. The magnitude of the GWP impact generated per process stage can be seen in Figure 3.

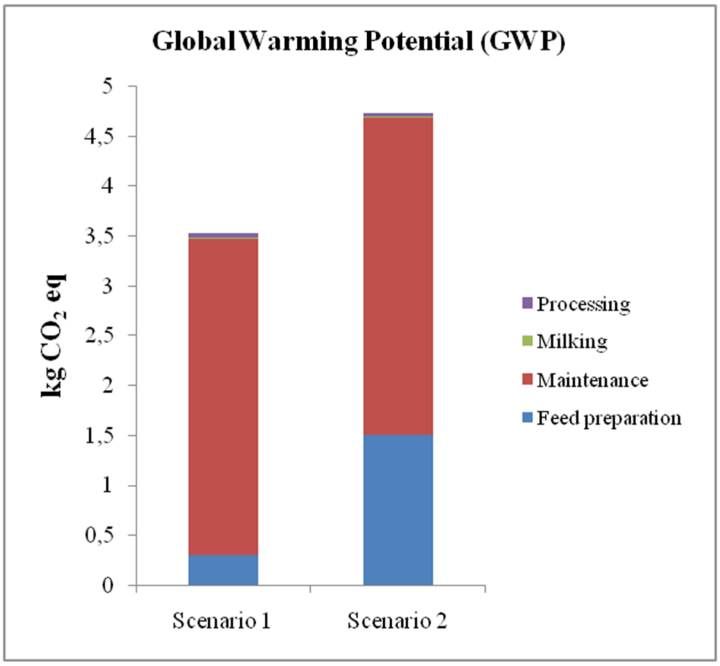

Figure 3. Comparison of GWP Impact of the two scenarios per process stage

The magnitude of the GWP impact generated per process stage in Figure 3 is not clearly visible for the milking and processing process, this is because the impact is very small. caused compared to the impact on the process of feed preparation and rearing. The process of feed preparation and rearing accounted for 8.29% and 90.34%, respectively, of the GWP impact caused in scenario 1 and 31.71% and 67.23% of the GWP impact caused in scenario 2. The use of electricity in livestock systems is present in every process, electricity is almost unavoidable in our daily lives, including for the life of livestock on farms. Rantiang Ameh Farm is a traditional local farm and many of its activities are carried out manually with human labor. In every stage of the process on the farm there is electricity usage even in small amounts.

Table 4. The Magnitude of The GWP Impact per Process Stage in Scenario 1 and Scenario 2

LCI	GWP Impact per Process (kg CO_2 eq/FPCM of Milk)				
	Feed preparation	Maintenance	Milking	Processing	Total
Electricity Usage	0,162	0,134	0,000361	0,000564	0,29692
Soap	-	0,135	0,00313	0,00489	0,14302
LPG				0,031	0,031
Diesel oil	0,0314				0,0314

Table 4. showed the magnitude of the GWP impact from electricity use per process stage in scenario 1 and scenario 2. The impact values generated in scenario 1 and scenario 2 show the same value. The impact of GWP caused by the use of electricity in the feed preparation process is 1.19%, which is 0.00162 kg CO2 eq/ FPCM of milk and 98.14% in the rearing process, which is 0.134 kg CO2 eq/ FPCM of milk. The use of electricity in the maintenance process is in the lights used for lighting the cage and in the use of water pumps to meet water needs in the maintenance process.

The impact of using soap, detergent or dishwashing liquid on each process that uses it. The resulting impact values in scenario 1 and scenario 2 show the same value. The GWP impact caused by the use of soap was greatest in the 94.39% maintenance process, which was 0.135 kg CO2 eq/FPCM of milk. The most use of soap, detergent or dishwashing liquid in the maintenance process, which is used in cage cleaning activities carried out using detergent. While in the milking and processing process, only a small amount of dishwashing liquid is used to clean the equipment used.

The use of LPG (Liquefied Petrolium Gas) in the processing is for heating milk in the milk pasteurization process. The pasteurization process is carried out using the LTLT (Low Temperature Long Time) method. At UPS Rantiang Ameh, milk is heated at 65°C for 30 minutes. The GWP impact caused by the use of LPG is 0.031 kg CO2 eq/FPCM of milk.

The use of fossil fuels in the form of diesel is in the transportation of feed (feed transportation) to the cage. The use of diesel in scenarios 1 and 2 has the same GWP impact. This is because the amount of feed transported in scenarios 1 and 2 with the same amount differs only at the preparation stage (planted or taken directly from nature). From the description above, the hotspot at Rantiang Ameh Farm in scenario 1 (existing conditions, forage taken from nature) is at the stage of the maintenance process, while in scenario 2 (the planting of forage) is in the feed preparation process.

IV. Conclusion

Based on the results of the Life Cycle Inventory Analysis (LCIA) of pasteurized goat milk production at Rantiang Ameh Ranch with scenario 1 (existing conditions) and scenario 2 (planting forage feeds) that have been carried out, the amount of CO2 equivalent emissions that cause GWP impact in one cycle of pasteurized goat milk production in the scenario 1 is 3.52 kg CO2 eq/FPCM Milk and scenario 2 is 4.73 kg CO2 eq/FPCM Milk. The GWP impact caused in scenario 2 is greater than in scenario 1, this is due to the planting of forage that uses fertilizer in scenario 2 while in scenario 1 the forage feed is directly taken from nature. Hotspot at Rantiang Ameh Farm in scenario 1 is at the stage of the maintenance process, while in scenario 2 is in the feed preparation process.

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