JPII 11(1) (2022) 35-46

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

GREENHOUSE GAS EMISSIONS AND BIOGAS POTENTIAL FROM LIVESTOCK IN RURAL INDONESIA

A. P. Heriyanti*[1,4], P. Purwanto[2], H. Purnaweni[3], T. R. Fariz[4]

[1]Doctoral Program of Environmental Science, School of Postgraduate Studies, Universitas Diponegoro, Indonesia
[2]Department of Chemical Engineering, Faculty of Engineering, Universitas Diponegoro, Indonesia
[3]Department of Public Administration, Faculty of Social and Political Sciences, Universitas Diponegoro, Indonesia
[4]Department of Integrated Science, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Indonesia

DOI: 10.15294/jpii.v11i1.34465

Accepted: January 12th 2022. Approved: March 30th 2022. Published: March 31st 2022

ABSTRACT

The livestock sector is one of the most significant contributors to greenhouse gas (GHG) emissions. Jetak Village in Indonesia has a large livestock population, so it has the potential to be a reasonably high contributor to GHG emissions. Therefore, research is needed to calculate GHG from the livestock sector and calculate biogas potential. Besides, we also discuss data collection techniques that are important but often forgotten in GHG reduction studies in developing countries. This is useful as an effort and reference to reduce GHG emissions in rural areas, especially in Jetak Village. The GHG calculation uses the Tier-1 method, while the data on the potential for biogas utilization is obtained from manure production calculations and in-depth interviews. The calculation results show that the highest total GHG from livestock management in Jetak Village in 2017 was 1,106.69 tons CO_2-eq/year, while the lowest total GHG emissions in 2015 were 1,018.41 CO_2-eq Gg/year. Dairy cows are the biggest emitter in livestock management, with 4,919.61 tons of CO_2-eq/year, and laying hens are the lowest emitters with 1.39 tons CO_2-eq/year. Dairy cows are the largest contributor to GHG emissions in enteric fermentation with 9,680.52 tons CO_2-eq/year, and the lowest number of contributors is horses with 20.79 tons CO_2-eq/year. The potential of biogas in Jetak Village based on manure production is 137 installations. The positive community's perception supports this. It tends to be less valid regarding livestock population data used for GHG calculations, so we verified it during in-depth interviews. The in-depth interview process used local language to enhance the quality of responses. This research needs to be developed considering our findings that there are only 50 biogas installations, indicating the biogas potential is not being utilized to its full potential.

Keywords: biogas potential; greenhouse gas; livestock

INTRODUCTION

Climate change is caused by global warming, detrimental to human life and other living things. The negative impacts of climate change include rising sea surface temperatures and extreme weather changes that increase the potential for natural disasters such as floods, droughts, and cyclones (Naumann et al., 2018; Chen et al., 2020; Tabari, 2020). Climate change is triggered by increasing concentrations of greenhouse gases (Cassia et al., 2018). Greenhouse gases (GHG), such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFC), and perfluorocarbons (PFC), are produced from various human businesses and activities (Ministry of the Environment Indonesia, 2012).

***Correspondence Address**
E-mail: andhinaputri@mail.unnes.ac.id

Human business or activities produce GHG. The most significant GHG contributors in business sectors are electricity and heat. Besides that, other sectors, such as land-use change and management, road transport, residential buildings, chemicals, metals, and livestock rearing, also contribute (Lamb et al., 2021). The agricultural sector accounts for 10-12% of the total anthropogenic greenhouse gases (N_2O and CH_4), while the livestock sector accounts for about 14%-51% of anthropogenic greenhouse gases (mostly CH_4) (Grossi et al., 2019; Cheng et al., 2022). Many contributors make GHG emissions predicted to increase due to increasing food needs caused by changes in land use and increased meat consumption (Surmaini et al., 2011; Dhoubhadel et al., 2016).

As the most significant GHG contributor, the livestock sector can also be a key player in GHG mitigation (Rojas-Downing et al., 2017). One form of GHG mitigation in the livestock sector is biogas (Hnyine et al., 2016; Hou et al., 2017). The important thing in determining the form of GHG mitigation in the livestock sector is the measurement results (Nugrahaeningtyas et al., 2018). It includes feeding, animal manure systems, emission values, and the effects of the given mitigation practices (Gerber et al., 2013; Nugrahaeningtyas et al., 2018). Therefore, this paper measures the value of GHG in the livestock sector and discusses biogas as one form of mitigation.

Indonesia is one of the countries in Southeast Asia which is the largest contributor of methane gas from the livestock sector (Boonyanuwat et al., 2013; Nugrahaeningtyas et al., 2018). The majority of livestock contributors in Indonesia come from rural areas, where most of the poor are also found there (Swastika, 2011; Ahuja, 2013). Therefore, the selected research location is rural Indonesia, Jetak Village. The agriculture and livestock sector is one of the leading sub-sectors there. In 2014-2019, it had 8,400 livestock, 12,498 small livestock, and 170,978 poultry. Jetak Village is assumed to have a considerable GHG potential from the livestock sector from the data (Putri et al., 2020). Based on this, it is necessary to research to calculate the amount of GHG produced from the livestock sector and calculate the potential for biogas energy development in Jetak Village to reduce GHG in rural areas.

The GHG from the livestock sector has been calculated through research on a regional scale such as research by Li et al. (2016), Mottet et al. (2017), Nugrahaeningtyas et al. (2018), Zuratih and Widiawati (2019), Das et al. (2020), Ammar et al. (2020), Arifin et al. (2021), and Sarah et al. (2021). This research also measures GHG in the livestock sector because this is urgent, but the research capacity is still limited in developing countries (Munidasa et al., 2021). The research mentioned has not explained the stages of data collection that can be applied to other areas. At the same time, the important thing in the study of GHG reduction in developing countries is fundamental technical aspects such as data and methodologies (Umemiya et al., 2017; Kawanishi & Fujikura, 2018; Umemiya et al., 2020). GHG data collection and mitigation potential through interviews have not been well researched. This is useful for novice researchers and those with few resources (Shan et al., 2017; DeJonckheere & Vaughn, 2019). Focusing on this research gap, we as researchers calculate GHG from the livestock sector, discuss the potential for using biogas to reduce greenhouse gases, and discuss the stages of data collection in Jetak Village, Indonesia. Researchers provide recommendations for the essential steps to follow to calculate GHG and find out the potential for using biogas. The research results will become new data as a reference and recommendation for policymakers in biogas energy development programs, especially in rural Indonesia, to implement policies towards an Energy Independent Village (*Desa Mandiri Energi*).

METHODS

This research is located in Jetak Village, Semarang Regency, Indonesia (Figure 1). Based on its topography, the research location is a highland and is located on the slopes of Mount Merbabu (Putri et al., 2020). Land use in Jetak Village includes agricultural land because most of the population makes a living as farmers (Mediatati & Nababan, 2019). The research stages include data collection and analysis techniques to determine the GHG value and the potential for biogas utilization at the research location.

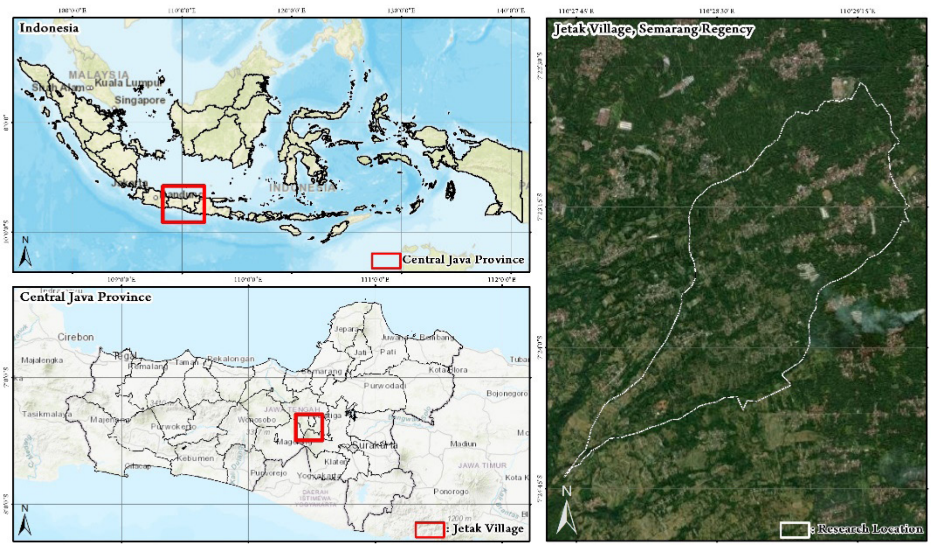

Figure 1. Research Location

The GHG value of the livestock sector in this research uses the Tier-1 method. Although Tier-2 and Tier-3 methods are considered more representative, they need detailed information about livestock not available in developing countries like Indonesia (Nugrahaeningtyas et al., 2020). In the Tier-1 method, the data used are livestock population data and Emission Factors (FE) values of CH_4 and N_2O of each kind of livestock. In calculating methane gas (CH_4) emissions in the livestock sector are as follows:

First, animal unit determination correction factor. Based on the Ministry of the Environment Indonesia (2012), dairy cattle, the total population obtained at the research site must be multiplied by a correction factor of 0,75 for dairy cattle and 0,72 for beef cattle and buffalo. This correction factor was found in the structure of the livestock population in Indonesia in 2006. Second, animal unit determination. In the calculation of the population or animal unit, the results obtained are based on the calculation of the number of populations multiplied by the correction factor set for the type of dairy cow that is assumed to be an Animal Unit (AU) with the following formula:

$$N_{(T)} \textit{in animal Unit} = N_{(X)} * k_{(T)}$$

Where:
$N_{(T)}$ = Number of livestock in animal unit
$N_{(X)}$ = Total livestock population
$k_{(T)}$ = Correction factor (0,75 dairy cow ; 0,72 beef cattleand buffalo)
T = Livestock type

Third, calculation of methane gas emissions from enteric fermentation. Emissions of methane gas (CH_4) are calculated from the enteric fermentation of livestock. The Tier-1 method requires activity data in livestock population data in animal units and methane gas emission factors (CH_4) from enteric fermentation. Emissions of methane gas (CH_4) from enteric fermentation can be calculated using the following formula:

$$CH_{4Enteric} = EF_{(T)} * N_{(T)} * 10^{-6}$$

Where:
$CH_{4Enteric}$ = Emission of methane gas from enteric fermentation, Gg CH_4/year
$EF_{(T)}$ = Emission factors for certain livestock breeds, kg CH_4 animal/year
$N_{(T)}$ = Total population of certain types, Ani mal Unit
T = Livestock type

Fourth, calculation of methane gas (CH_4) emissions from animal manure. Methane gas emissions (CH_4) calculated from livestock manure using the Tier-1 method require activity data in the form of livestock population data in Animal Units and methane gas emission factors (CH_4) from livestock manure from each type of livestock presented in the table. The calculation of methane gas (CH_4) emissions from livestock manure use the following formula:

$$CH_{4Manure} = EF_{(T)} * N_{(T)} * 10^{-6}$$

Where:
$CH_{4Manure}$ = Emissions of methane gas from live stock manure, Gg CH_4/year
$EF_{(T)}$ = Emission factors for certain livestock breeds, kg CH_4 unit/year
$N_{(T)}$ = Total population of certain types, Ani mal Unit
T = Livestock type

Fifth, CH_4 emissions total livestock sector. Calculation of total CH_4 emissions in the livestock sector is obtained from adding methane gas emissions (CH_4) of enteric fermentation with methane gas emissions (CH_4) of livestock manure. The calculation of total methane (CH_4) emissions uses the following formula:

$$\text{Total Emission}_{CH4} = \text{Emission } CH_4 \text{ (fermentation)} + \text{Emission } CH_4 \text{ (manure)}$$

Where:
Emission_{CH4} Total = total amount of CH_4 emission from the livestock sector
Emission_{CH4} (fermentation)= total amount of CH_4 emission from enteric fermentation
Emission_{CH4} (manure) = total amount of CH_4 emission from manure

The potential use of biogas in this research includes calculating the number of manure and public perception. Community perceptions are socioeconomic characteristics of potential that play an essential role in ensuring that biogas can be adequately utilized (Wahyudi, 2017). Data collection techniques to obtain information on the potential for biogas utilization are field studies and in-depth interviews of 72 respondents. After the information on the potential for biogas utilization has been obtained, we then describe the stages of data collection to determine the potential for biogas utilization in Jetak Village.

RESULTS AND DISCUSSION

Livestock population data in Jetak Village from farm profile data in Getasan District is secondary data needed in this research. Jetak Village consists of 12 subvillages: Setugur, Jayan, Dukuh, Tosoro A, Tosoro B, Weru A, Weru B, Kemiri, Legok, Kendal, Gajian, and Jetak. The livestock population in Jetak Village consists of ruminants (beef cattle, dairy cows, horses, goats, and sheep) and non-ruminant livestock (poultry) (Table 1). The number of livestock is because the livestock sector is one of the main livelihoods for some people in Jetak Village.

Table 1. Number of Livestock and Poultry in 2014 – 2019

Kind of Livestock	Year					
	2014	2015	2016	2017	2018	2019
Beef cattle	235	98	129	101	133	91,44
Dairy cows	1.278	1.235	1.266	1.286	1.229	1263,75
Buffalo	0	0	0	0	0	0
Sheep	388	443	316	559	486	394,56
Goat	305	147	157	37	160	211
Pig	1.476	1.390	1.322	1.678	1.485	1544
Horse	6	7	13	15	5	9
Free-range Chicken	854	1.143	1.860	2.575	2.654	2886
Chickens	1.135	2.547	5.392	11.765	9.541	15632
Laying hens	4.237	7.687	11.542	27.540	28.551	30116
Duck	512	566	548	587	610	498

From the data from 2014 to 2019, the livestock population in Jetak Village was dominated by 3.321 ducks, 11.972 free-range chickens, 46.012 chickens, and 109.673 laying hens. For the kind of ruminant livestock, there is a population of 788 beef cattle, 7.557 dairy cattle, 2.586 sheep, 1.017 goats, and the least livestock species are horses (55 horses).

In Indonesia, livestock population data is collected by the Central Statistics Agency (BPS) through the Agricultural Survey (SUTAS). These data are easy to find on a regional scale, such as research by Arifin et al. (2021) and Sarah et al. (2021). The challenge in collecting village-level livestock population data in Indonesia is not available on the internet, so one solution is to retrieve the data at the Jetak Village Office (*Balai Desa*). We were constrained by not finding livestock population data at the Jetak Village Office in the data collection process, so we looked for the data at the Getasan District Office (*Balai Kecamatan*).

Based on Moss et al. (2016), the livestock population data found significant data duplication due to lack of institutional coordination among stakeholders, limited access to data, and being under-resourced. In Jetak Village, the discrepancy of the livestock population in the farm profile data with the actual conditions is caused by several factors such as death and livestock theft. The livestock population data is obtained from the farm profile data needs to be verified through interviews with the community.

The results of the calculation of methane gas (CH_4) emissions from enteric fermentation from the total population of all livestock (including Animal Units) obtained the amount of methane gas (CH_4) emissions from enteric fermentation in Jetak Village. From the kind of livestock, dairy cows contributed the most to methane (CH_4) emissions from enteric fermentation (9.680,52 tons CO_2-eq), and the smallest contributor to methane (CH_4) emissions from enteric fermentation was horses (20,79 tons CO_2-eq). From the CH_4 emissions per year, 2014 had the highest emission contributor (1.975,53 tons CO_2-eq), and 2015 had the smallest CH_4 emission contributor (1.772,77 tons CO_2-eq). The methane gas (CH_4) emissions from enteric fermentation in the livestock sector in Jetak Village were calculated using the Tier-1 method. Overall methane gas (CH_4) emission from enteric fermentation is in Figure 2.

Kind Of Livestock	Total CH4 Emissions from Manure management (Tons) in 2014-2019								Total CH4 Emissions from Enteric Fermentation (Tons) 2014-2019							
	Year								Year							
	2014	2015	2016	2017	2018	2019	Number of Emissions	CO2e	2014	2015	2016	2017	2018	2019	CH4 (Gg CH4)	CH4 (Gg CO2- eq)
Beef cattle	0,24	0,1	0,13	0,10	0,13	0,09	0,79	16,54	11,07	4,6	6,06	4,74	6,26	4,30	37,02	777,44
Dairy cows	39,62	38,29	39,25	39,85	38,08	39,18	234,27	4.919,61	77,96	75,35	77,23	78,42	74,94	77,09	460,98	9.680,52
Buffalo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sheep	0,08	0,09	0,06	0,11	0,1	0,08	0,52	10,86	1,94	2,21	1,58	2,79	2,43	1,97	12,93	271,56
Goat	0,07	0,03	0,03	0,01	0,04	0,05	0,22	4,7	1,53	0,74	0,79	0,19	0,8	1,06	5,09	106,79
Pig	10,33	9,73	9,25	11,75	10,4	10,81	62,27	1.307,57	1,48	1,39	1,32	1,68	1,49	1,54	8,9	186,8
Horse	0,01	0,02	0,03	0,03	0,01	0,02	0,12	2,53	0,11	0,13	0,23	0,27	0,09	0,16	0,99	20,79
Free-range Chicken	0,02	0,02	0,04	0,05	0,05	0,06	0,24	5,03	-	-	-	-	-	-	-	-
Chickens	0,02	0,05	0,11	0,24	0,19	0,31	0,92	19,33	-	-	-	-	-	-	-	-
Laying hens	0,08	0,15	0,23	0,55	0,57	0,60	2,19	46,06	-	-	-	-	-	-	-	-
Duck	0,01	0,01	0,01	0,01	0,01	0,01	0,07	1,39	-	-	-	-	-	-	-	-
Number Emisi	**50,48**	**48,5**	**49,14**	**52,7**	**49,58**	**51,20**	-	-	**94,07**	**84,42**	**87,2**	**88,08**	**86**	**86,12**	-	-
CO2e	**1.060,04**	**1.018,41**	**1.031,98**	**1.106,69**	**1.041,23**	**1.075,271**	-	-	**1.975,53**	**1.772,77**	**1.831,30**	**1.849,67**	**1.806,08**	**1.808,525**	-	-

Figure 2. Total CH_4 Emissions from Enteric Fermentation (Tons) and Manure Management (Tons) 2014-2019

Based on Figure 2, the highest number is dairy cows with 460,98 (Gg CH_4), equivalent to CH_4 emissions of 9.680,52 (Gg $C0_2$ eq) from 2014 to 2019. This data is per field conditions where most of the people in Jetak Village have dairy farms, so this species is the highest contributor to gas emissions from rumen digestion. Of the global anthropogenic CH_4, enteric CH_4 production from ruminants accounts for the highest, around 17 to 37% (Alemu et al., 2011; Cottle et al., 2011; Knapp et al., 2014). CH_4 gas from the livestock sector as a whole account for about 37%

of all human-induced CH_4 emissions, with 89% of emissions coming from enteric fermentation of livestock (Jiao et al., 2014).

In the livestock sector, the production of methane gas (CH_4) from enteric fermentation is the largest emitter of greenhouse gases, followed by methane (CH_4) from land applications and manure management systems (Klevenhusen et al., 2011; Adesogan et al., 2013; Hristov et al., 2013). Based on meat production, dairy cows accounted for 20% of total emissions, while emissions from beef cattle accounted for the largest, around 41% of total emissions from the livestock sector (Gerber et al., 2013).

Methane gas emissions (CH_4) from manure management were also calculated for livestock groups in 12 sub-villages in Jetak village: Setugur, Jayan, Dukuh, Tosoro A, Tosoro B, Weru A, Weru B, Kemiri, Legok, Kendal, Gajian, and Jetak. A comparison of calculation results of the burden of methane gas emissions produced per year was carried out to determine which year is the largest and smallest contributor to methane gas (CH_4) emissions from manure management. The result of methane gas emission (CH_4) obtained is in the form of tons of CH_4 per year converted into tons of CO_2-equivalent per year using the Global Warming Potential value of 21 for CH_4 (Eggleston et al., 2006).

The calculation results obtained the methane gas (CH_4) emissions from livestock management in Jetak Village. The highest total greenhouse gas emissions from livestock management in Jetak Village were in 2017 with 1.106,69 tons of CO_2-eq/year, while the lowest total greenhouse gas emissions were in 2015 with 1.018,41 CO_2-eq Gg/year. Judging from the kind of livestock, dairy cows are the largest contributor to emissions in livestock management with 4.919,61 tons of CO_2-eq/year, followed by pigs with 1.307,57 tons of CO_2-eq/year. Laying hens are the lowest emitter with 1,39 tons CO_2-eq/year. The calculation results of methane gas (CH_4) emissions from manure management from all livestock groups in each sub-district in Jetak Village is in Figure 2. The livestock population in Figure 2 includes the number of livestock populations in the Animal Unit.

The high value of CH_4 emission gas resulting from manure management is influenced by forage feed for dairy cows in Jetak Village. Most of the farmers in Jetak Village provide high-fiber feed such as grass mixed with bran. This fact is under previous research where one of the factors affecting methane gas (CH_4) emissions from manure management is the kind of feed given to livestock (Prayitno et al., 2014). Livestock that consumes fibrous feed produces manure with higher methane gas (CH_4) compared to livestock that consumes feed from grains (Ishak et al., 2019). Animal feed with high nutrition produces low methane production (Criscioni & Fernández, 2016; Elghandour et al., 2017; Romero et al., 2020), such as concentrate feed. Forage feeds contribute higher greenhouse gas emissions, primarily forage feeds with high crude fiber. Environmental factors also support the potential for emissions resulting from the fermentation process of feed from the cow's rumen because people usually combust their feed, such as bran from rice (Ishak et al., 2019).

The livestock sector produces a burden of greenhouse gas emissions influenced by the number of livestock populations, activity of microorganisms, manure management, kinds of animal feed, and environmental temperature. Methane gas from manure is influenced by bacterial activity in anaerobic degradation (Borhan et al., 2011; Moset et al., 2015). Microorganisms and optimal temperature for each specific microorganism activity are one way to control emissions (Syarifuddin et al., 2019). The methanogenesis process is highly dependent on the type of food quality, low temperature, and storage time (Klevenhusen et al., 2011).

The emission load for nitrous oxide (N_2O) gas is expressed in tons of N_2O per year, converted into tons of CO_2-equivalent using a GWP value of 310 for N_2O (Eggleston et al., 2006). Manure management's direct and indirect nitrous oxide (N_2O) emissions were calculated for each livestock group in 12 sub-villages in Jetak village: Setugur, Jayan, Dukuh, Tosoro A, Tosoro B, Weru A, Weru B, Kemiri, Legok, Kendal, Gajian, and Jetak.

The calculation results make comparisons every year to determine the largest and smallest contributor to direct and indirect nitrous oxide (N_2O) gas emissions from livestock manure management. The calculation results obtained the amount of nitrous oxide (N_2O) gas emissions directly and indirectly from livestock manure management in Jetak Village. 2018 was the largest direct contributor to nitrous oxide (N_2O) gas emissions was 36,91 tons of CO_2-eq from a total population of 44.854 livestock, while the smallest indirect contributor to nitrous oxide (N_2O) gas emissions in 2014 was 2,62 tons. CO_2-eq. The smallest direct contributor to nitrous oxide (N_2O) gas emissions was in 2015 with 18,67 tons CO_2-eq of nitrous oxide (N_2O) gas emissions from a total population of 15.264 livestock, while the smallest contributor to indirect nitrous oxide gas emissions was 2015 was 2,42 tons CO_2-eq.

Kind Of Livestock	Direct N_2O Emissions (Ton)						Indirect N_2O Emissions (Ton)					
	2014	2015	2016	2017	2018	2019	2014	2015	2016	2017	2018	2019
Beef cattle	0,01	0	0	0	0,06	0,00	0	0	0	0	0	0,00
Dairy cows	0,05	0,05	0,05	0,05	0,05	0,05	0,01	0,01	0,01	0,01	0,01	0,0
Buffalo	-	-	-	-	-	-	-	-	-	-	-	-
Sheep	0	0	0	0	0	0,00	0	0	0	0	0	0,0
Goat	0	0	0	0	0	0,00	0	0	0	0	0	0,0
Pig	0	0	0	0	0	0,00	0	0	0	0	0	0,0
Horse	0	0	0	0	0	0,00	0	0	0	0	0	0,0
Free-range Chicken	0	0	0	0	0	0,00						
Chickens	0	0	0	0	0	0,00	-	-	-	-	-	-
Laying hens	0	0	0	0	0	0,00	-	-	-	-	-	-
Duck	0	0	0	0	0	0,00	-	-	-	-	-	-
Total	**0,07**	**0,06**	**0,06**	**0,07**	**0,12**	**0,07**	**0,01**	**0,01**	**0,01**	**0,01**	**0,01**	**0,0**
CO2-eq	20,39	18,67	19,35	21,05	36,91	21,02	2,62	2,42	2,48	2,53	2,45	2,48

Figure 3. Total Direct and Indirect N_2OEmissions from Manure Management (Tons) in 2014-2019

The calculation results of total direct and indirect nitrous oxide (N_2O) gas emissions in Jetak Village from 2014-2019 are presented in Figure 3. The livestock population in Figure 3 includes the number of livestock populations in the Animal Unit.

Table 2. Total Gas Emissions from Livestock and Manure in 2014-2019

Emission Category	2014		2015		2016		2017		2018		2019	
	CH_4 (Gg CH_4)	CH_4 (Gg CO_2 e)	CH_4 (Gg CH_4)	CH_4 (Gg CO_2 e)	CH_4 (Gg CH_4)	CH_4 (Gg CO_2 e)	CH_4 (Gg CH_4)	CH_4 (Gg CO_2 e)	CH_4 (Gg CH_4)	CH_4(Gg CO_2 e)	CH_4 (Gg CH_4)	CH_4 (Gg CO_2 e)
Enteric Fermentation	94,7	1975,53	84,42	1772,77	87,2	1831,3	88,08	1849,67	86	1806,08	86,12	1808,52
CH_4 Emission	50,48	1060,04	48,5	1018,41	49,14	1031,98	52,7	1106,69	49,58	1041,23	51,2	1075,8
N_2O Manure Manure System	0,07	20,39	0,06	18,67	0,06	19,35	0,07	21,05	0,12	36,91	0,067	21,02
Total	145,25	**3055,96**	132,98	**2809,85**	136,4	**2882,63**	140,85	**2977,41**	135,7	**2884,22**	137,387	**2905,34**

Based on Table 2, the total greenhouse gas emissions in Jetak Village in 2014 were the largest (3.055,9), dominated by CH_4 gas from the effluent of enteric feed fermentation activities in ruminant livestock species with 1.975,53 (Gg CO_2-eq). Meanwhile, the highest emission of CH_4 from manure was in 2017 with 1.106,69 (Gg CO_2-eq), and the highest N_2O produced from manure management was in 2018 with 36,91 (Gg CO_2-eq). The factor influencing these results is that the population of ruminants in Jetak Village is greater than that of other kinds of livestock. Another factor that affects the high greenhouse gas emissions in Jetak Village is the culture. Most people with livestock in Jetak do not manage their livestock manure properly. Manure is left in their fields without any processing to become a contributor to N_2O from livestock manure released directly into the air. This statement aligns with Samiaji (2012), where N_2O gas is the largest contributor to greenhouse gases because it impacts 298 times more heat per unit weight than carbon dioxide.

The calculation results obtained the highest total greenhouse gas emissions from livestock management in Jetak Village in 2017 with 1.106,69 tons of CO_2-eq /year (Figure 2). In that year, we analyzed data referring to the cow population in Jetak Village. The results showed that the potential for biogas made from dairy cow waste in 2019 was 42.125,00 kg of manure/day (Table 3). The value of the manure has a gas potential of around 968,875 m^3/kg with a methane content of 678,2 m^3. Every 1 m^3 of methane gas is equivalent to 0,46 kg of LPG; 0,62 liters of kerosene; 0,52 liters of diesel; 0,80 liters of fuel, and 3,50 kg of firewood (Putri et al., 2019). Thus, the dairy cow waste produced in Jetak Village is equivalent to 311.977 kg of LPG, equivalent to 420,5 liters of kerosene, 352,67 liters of diesel, 542,57 liters of gasoline, and 2373,74 kg of firewood.

Table 3. Manure Production, Gas, and Methane Potential in Jetak Village

Sub Village	Population	Manure (kg/day)	Potential Gases (m^3 /kg)	Methane (m^3)	Biogas installation
Kendal	327	8175	188,025	131,6175	27
Jetak	263	6575	151,225	105,8575	22
Kemiri	175	4375	100,625	70,4375	14
Setugur	233	5825	133,975	93,7825	19
Weru A	221	5525	127,075	88,9525	18
Weru B	176	4400	101,2	70,84	14
Tosoro A	114	2850	65,55	45,885	9
Tosoro B	176	4400	101,2	70,84	14
Total	1685	42125	968,875	678,2125	137

According to the instructions for using the Special Allocation Fund for Rural Energy (Minister of Energy and Mineral Resources Indonesia, 2015), the household scale is with a depth of 1.5 m with a diameter of 1.50 m. The contents of the biogas container are 612.30 kg (water and manure), with a ratio of 1:1. So each household-scale container requires approximately 306.15 kg of manure.

Table 3 shows the potential distribution of biogas installations as renewable alternative energy in Jetak Village, Getasan District. Referring to these data, household-scale biogas installations in Jetak Village can be built as many as 137 installations with concrete as a base material if referring to the number of potential renewable energy. In selecting the type of installation to be built, it must be adjusted to the characteristics of the community using biogas and the location for making biogas installations. This fixed dome type is built with cement, sand, stone, and brick as raw materials. This model has an airtight design and a solid structure to prevent leakage of the gas produced. The advantages of this model are easy maintenance and low cost, while the disadvantages are that it takes a long time in the manufacturing process, is prone to cracking, the location cannot be moved, and the construction cost is quite expensive. This fixed dome model has relatively large pores in the digester, which causes the gas produced to leak easily, making it difficult to detect early and make repairs if there is damage, especially leaks (Wahyuni, 2011).

The construction of biogas installations in Jetak Village can be carried out in stages as a form of mitigating greenhouse gases in Jetak Village, which are produced from the livestock sector and contribute to global warming (Paolini et al., 2018; Putri et al., 2019; Pochwatka et al., 2020). The use of biogas in Jetak Village has been started since 2008 after Jetak Village received assistance from the government through the Special Budget Fund (*Dana Anggaran Khusus*). Assistance was given to three families with 15-20 cows per family and construction of a digester with a capacity of 30 m^3, which produces 18 m^3 of gas/day (Purwanto, 2018). Over time, biogas utilization does not go well due to several factors such as damage at several points of the biogas installation that has not been repaired and the fixed dome installation did not meet the standards. As a result, to identify the root of the problem, it is preferable to examine the community's perception of biogas in several aspects: new technology, installation techniques, biogas benefits, economy, and environment.

In general, the user community in Jetak's perceptions of new technology show enthusiasm and great appreciation for the energy of this biogas. Most people understand that animal waste problems may be effectively handled by using biogas while also benefiting everyday energy demands. Some elements must be addressed when introducing new technologies if there are variances in attitudes in community groups in the face of technological innovation based on the community groups' features.

In Installation technique, Jetak's biodigester design differs somewhat from previous biodigesters. Some users have issues running the digester due to processing efficiency and efficacy. Furthermore, extra energy is required to sift, combine, and stir before entering the central installation. In theory, biogas helps both the user community and the neighboring communities. Indirectly turning cow manure into biogas energy can help prevent the pollution of foul aromas that create societal disputes.

The Jetak user community may save between 50 and 60 thousand rupiahs per month using biogas. These savings might indirectly assist the user community in managing their money. The biogas leftovers in the form of sludge are still not being utilized efficiently by the Jetak user community. After drying, these leftovers are solely left in the reservoir and used as fertilizer on their property. The anaerobic fermentation leftover biogas fertilizer comprises nutrients, heavy metals, pesticide residues, and harmful microorganisms (Chen et al., 2020). Biogas users respond positively to environmental cleanliness, particularly around the barn. Biogas technology has an indirect positive influence on environmental health and human and cattle health. Overall, the Jetak user community has not established a zero-waste approach.

The community's perception of biogas users was favorable, particularly new technology and biogas benefit. Several aspects are still constrained so that the sustainability of biogas used by the community has not yet reached its maximum. Government has a vital role in overcoming these obstacles by evaluating and monitoring the use of biogas by the community so that biogas installations do not become useless materials (Putri et al., 2020).

Based on manure production, in Jetak Village, there should be 137 units of household-scale biogas installations, but in reality, there are only 50 biogas installations that have been built. Therefore, this research can be developed by examining the factors affecting the adoption of biogas production, such as household's level of income, household size, and awareness of the different energy sources available (Ngcobo et al., 2020). In the technique of collecting data through interviews, we suggest using the local language (*krama inggil*) to enhance the quality of responses. In addition, we also asked for assistance during data collection by the field coordinator in charge of biogas in Jetak Village.

CONCLUSION

It can be concluded that the highest total GHG from livestock management in Jetak Village in 2017 was 1.106,69 tons CO_2-eq/year, while the lowest total GHG emissions in 2015 were 1.018,41 CO_2-eq Gg/year. Dairy cows are the biggest emitter in livestock management from livestock, with 4.919,61 tons of CO_2-eq/year, followed by pigs with 1.307,57 tons of CO_2-eq/year, and laying hens are the lowest emitters with 1,39 tons CO_2-eq/year. From enteric fermentation, the highest GHG was in 2014 with 1.975,53 tons CO_2-eq/year, while the lowest emission was in 2015 with 1.772,77 tons CO_2-eq/year. Dairy cows are the largest contributor to GHG emissions in enteric fermentation with 9.680,52 tons CO_2-eq/year, followed by beef cattle with 777,44 tons CO_2-eq/year, and the lowest number of contributors is horses with 20,79 tons CO_2-eq/year. The potential for renewable energy from cattle waste is 42,125 Kg of manure /day or equivalent to 968.875 m^3 of gas with a methane content of 678,2 m^3. This amount can be utilized through biogas installations of 137 units. Moreover, this is supported by positive public perception. The reality in the field only found 50 biogas installations so that further research can be done such as factors affecting the adoption of biogas production. Our findings also show a discrepancy in the livestock population from livestock population data with the reality in the field due to livestock deaths and theft. We suggest verifying livestock population data through in-depth interviews. The interview process should use the local language (*krama inggil*) to enhance the quality of responses and ask for assistance from local communities in charge of biogas.

ACKNOWLEDGEMENTS

Acknowledgements are conveyed to Direktorat Jenderal Penguatan Riset dan Pengembangan Kemenristekdikti for their support through the DRPM funding source on the doctoral dissertation research scheme (No: 258-48/UN7.P4.3/PP/2019).

REFERENCES

Adesogan, T., Yang, W., Lee, C., Gerber, P. J., Henderson, B., & Tricarico, J. M. (2013). Mitigation of methane and nitrous oxide emissions from animal—SPECIAL TOPICS. *J. Anim. Sci*, *91*, 5045-5069.

Ahuja, V. (2013). Asian Livestock: Challenges. *Opportunities and the Response*. Proceedings of an international policy forum held in Bangkok, Thailand

Alemu, A., Ominski, K. H., & Kebreab, E. (2011). Estimation of enteric methane emissions trends (1990–2008) from Manitoba beef cattle using empirical and mechanistic models. *Canadian Journal of Animal Science*, *91*(2), 305-321.

Ammar, H., Abidi, S., Ayed, M., Moujahed, N., deHaro Martí, M. E., Chahine, M., ... & Hechlef, H. (2020). Estimation of Tunisian greenhouse gas emissions from different livestock species. *Agriculture*, *10*(11), 562.

Arifin, M. D., Gunawan, S. G., Amin, M., & Mubarak, H. (2021, July). Green house gases emission of livestock sector in East Kalimantan using Tier-1 2019 refinement. In *IOP Conference Series: Earth and Environmental Science* (Vol. 807, No. 2, p. 022028). IOP Publishing.

Boonyanuwat, K., Lavan, K., Sithambaram, S., & Widyawati, Y. (2013). Improved inventory and mitigation of greenhouse gases in livestock production in South East Asia. *A final report submitted to Livestock Emissions and Abatement Research Network (LEARN).*

Borhan, M. S., Capareda, S. C., Mukhtar, S., Faulkner, W. B., McGee, R., & Parnell, C. B. (2011). Greenhouse gas emissions from ground level area sources in dairy and cattle feedyard operations. *Atmosphere*, *2*(3), 303-329.

Cassia, R., Nocioni, M., Correa-Aragunde, N., & Lamattina, L. (2018). Climate change and the impact of greenhouse gasses: CO2 and NO, friends and foes of plant oxidative stress. *Frontiers in plant science*, *9*, 273.

Chen, J., Wang, Z., Tam, C. Y., Lau, N. C., Lau, D. S. D., & Mok, H. Y. (2020). Impacts of climate change on tropical cyclones and induced storm surges in the Pearl River Delta region using pseudo-global-warming method. *Scientific reports*, *10*(1), 1-10.

Cheng, M., McCarl, B., & Fei, C. (2022). Climate Change and Livestock Production: A Literature Review. *Atmosphere*, *13*(1), 140.

Cottle, D. J., Nolan, J. V., & Wiedemann, S. G. (2011). Ruminant enteric methane mitigation: a review. *Animal Production Science*, *51*(6), 491-514.

Criscioni, P., & Fernández, C. (2016). Effect of rice bran as a replacement for oat grain in energy and nitrogen balance, methane emissions, and milk performance of Murciano-Granadina goats. *Journal of Dairy Science*, *99*(1), 280-290.

Das, N. G., Sarker, N. R., & Haque, M. N. (2020). An estimation of greenhouse gas emission from livestock in Bangladesh. *Journal of advanced veterinary and animal research*, *7*(1), 133.

DeJonckheere, M., & Vaughn, L. M. (2019). Semistructured interviewing in primary care research: a balance of relationship and rigour. *Family medicine and community health*, *7*(2), e000057.

Dhoubhadel, S. P., Taheripour, F., & Stockton, M. C. (2016). Livestock Demand, Global Land Use Changes, and Induced Greenhouse Gas Emissions. *Journal of Environmental Protection*, *7*(07), 985.

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). 2006 IPCC guidelines for national greenhouse gas inventories.

Elghandour, M. M. Y., Vázquez, J. C., Salem, A. Z. M., Kholif, A. E., Cipriano, M. M., Camacho, L. M., & Márquez, O. (2017). In vitro gas and methane production of two mixed rations influenced by three different cultures of Saccharomyces cerevisiae. *Journal of Applied Animal Research*, *45*(1), 389-395.

Gerber, P. J., Hristov, A. N., Henderson, B., Makkar, H., Oh, J., Lee, C., ... & Oosting, S. (2013). Technical options for the mitigation of direct methane and nitrous oxide emissions from livestock: a review. *animal*, *7*(s2), 220-234.

Grossi, G., Goglio, P., Vitali, A., & Williams, A. G. (2019). Livestock and climate change: impact of livestock on climate and mitigation strategies. *Animal Frontiers*, *9*(1), 69-76.

Hnyine, Z. T., Sagala, S., Lubis, W., & Yamin, D. (2016, February). Benefits of rural biogas implementation to economy and environment: Boyolali case study. In *Forum Geografi* (Vol. 29, No. 2, pp. 115-128).

Hou, J., Zhang, W., Wang, P., Dou, Z., Gao, L., & Styles, D. (2017). Greenhouse gas mitigation of rural household biogas systems in China: a life cycle assessment. *Energies*, *10*(2), 239.

Hristov, A. N., Ott, T., Tricarico, J., Rotz, A., Waghorn, G., Adesogan, A., ... & Firkins, J. L. (2013). Special topics—Mitigation of methane and nitrous oxide emissions from animal operations: III. A review of animal management mitigation options. *Journal of Animal Science*, *91*(11), 5095-5113.

Ishak, A. B. L., Takdir, M., & Wardi, W. (2019). Estimasi emisi gas rumah kaca (grk) dari sektor peternakan tahun 2016 di Provinsi Sulawesi Tengah. *Jurnal Peternakan Indonesia (Indonesian Journal of Animal Science)*, *21*(1), 51-58.

Jiao, H. P., Dale, A. J., Carson, A. F., Murray, S., Gordon, A. W., & Ferris, C. P. (2014). Effect of concentrate feed level on methane emissions from grazing dairy cows. *Journal of Dairy Science*, *97*(11), 7043-7053.

Kawanishi, M., & Fujikura, R. (2018). Evaluation of enabling factors for sustainable national greenhouse gas inventory in developing countries. *Int. J. Environ. Sci. Develop*, *9*(10), 290-297.

Klevenhusen, F., Kreuzer, M., & Soliva, C. R. (2011). Enteric and manure-derived methane and nitrogen emissions as well as metabolic energy losses in cows fed balanced diets based on maize, barley or grass hay. *Animal*, *5*(3), 450-461.

Knapp, J. R., Laur, G. L., Vadas, P. A., Weiss, W. P., & Tricarico, J. M. (2014). Invited review: Enteric methane in dairy cattle production: Quantifying the opportunities and impact of reducing emissions. *Journal of dairy science*, *97*(6), 3231-3261.

Lamb, W. F., Wiedmann, T., Pongratz, J., Andrew, R., Crippa, M., Olivier, J. G., ... & Minx, J. C. (2021). A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018. *Environmental research letters*.

Li, F., Cheng, S., Yu, H., & Yang, D. (2016). Waste from livestock and poultry breeding and its potential assessment of biogas energy in rural China. *Journal of Cleaner Production*, *126*, 451-460.

Mediatati, N., & Nababan, K. R. (2019). Voting Preferences at Getasan Sub-District in Semarang Regency Head Election. *International Journal of Multicultural and Multireligious Understanding*, *6*(5), 195-200.

Ministry of Energy and Mineral Resources Indonesia (Kementerian Energi dan Sumber Daya Mineral). (2015). Petunjuk Teknis Penggunaan Dana Alokasi Khusus Bidang Energi Perdesaan Tahun Anggaran 2015. Jakarta: Kementerian Energi dan Sumber Daya Mineral

Ministry of the Environment Indonesia (Kementerian Lingkungan Hidup). (2012). Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional Buku II Volume 3 Metodologi Perhitungan Tingkat Emisi dan Penyerapan Gas Rumah Kaca Pertanian Kehutanan dan Penggunaan Lahan Lainnya. Jakarta: Kementerian Lingkungan Hidup.

Moset, V., Poulsen, M., Wahid, R., Højberg, O., & Møller, H. B. (2015). Mesophilic versus thermophilic anaerobic digestion of cattle manure: methane productivity and microbial ecology. *Microbial biotechnology*, *8*(5), 787-800.

Moss, J., Morley, P., Baker, D., Al Moadhen, H., & Downie, R. (2016). Improving methods for estimating livestock production and productivity. *University of New England*.

Mottet, A., Henderson, B., Opio, C., Falcucci, A., Tempio, G., Silvestri, S., ... & Gerber, P. J. (2017). Climate change mitigation and productivity gains in livestock supply chains: insights from regional case studies. *Regional Environmental Change*, *17*(1), 129-141.

Munidasa, S., Eckard, R., Sun, X., Cullen, B., McGill, D., Chen, D., & Cheng, L. (2021). Challenges and opportunities for quantifying greenhouse gas emissions through dairy cattle research in developing countries. *Journal of Dairy Research*, *88*(1), 3-7.

Naumann, G., Alfieri, L., Wyser, K., Mentaschi, L., Betts, R. A., Carrao, H., ... & Feyen, L. (2018). Global changes in drought conditions under different levels of warming. *Geophysical Research Letters*, *45*(7), 3285-3296.

Ngcobo, L., Obi, A., Mamphweli, S., & Zantsi, S. (2020). Adoption and perceptions of biogas: Empirical evidence from rural households of Melani village in Raymond Mhlaba municipality. *African Journal of Science, Technology, Innovation and Development*, 1-9.

Nugrahaeningtyas, E., Baek, C. Y., Jeon, J. H., Jo, H. J., & Park, K. H. (2018). Greenhouse gas emission intensities for the livestock sector in Indonesia, based on the national specific data. *Sustainability*, *10*(6), 1912.

Nugrahaeningtyas, E., Baek, C. Y., Jeon, J. H., Song, J. I., & Park, K. H. (2020). Greenhouse gas emission intensity from Indonesian livestock sector. *Journal of Animal Behaviour and Biometeorology*, *6*(4), 109-115.

Paolini, V., Petracchini, F., Segreto, M., Tomassetti, L., Naja, N., & Cecinato, A. (2018). Environmental impact of biogas: A short review of current knowledge. *Journal of Environmental Science and Health, Part A*, *53*(10), 899-906.

Pochwatka, P., Kowalczyk-Juśko, A., Sołowiej, P., Wawrzyniak, A., & Dach, J. (2020). Biogas plant exploitation in a middle-sized dairy farm in Poland: energetic and economic aspects. *Energies*, *13*(22), 6058.

Prayitno, C. H., Fitria, R., & Samsi, M. (2014). Suplementasi Heit-Chrose pada Pakan Sapi Perah Pre-Partum Ditinjau dari Profil Darah dan Recovery Bobot Tubuh Post-Partum. *Jurnal Agripet*, *14*(2), 89-95.

Purwanto, P. (2018). Evaluation of Livestock Waste Management to Energy Biogas (Case Study: Jetak Village, Getasan Sub District). In *E3S Web of Conferences* (Vol. 73, p. 07013). EDP Sciences.

Putri, A., Purwanto, P., & Purnaweni, H. (2019). Potential Utilization of Dairy Cattle Waste into Biogas (Jetak Village, Semarang City, Central Java). In *E3S Web of Conferences* (Vol. 125, p. 14014). EDP Sciences.

Putri, A., & Purnaweni, H. (2020, March). Perception of the community on the use of biogas as alternative energy (Case study: Jetak Village, Getasan sub district). In *IOP Conference Series: Earth and Environmental Science* (Vol. 481, No. 1, p. 012045). IOP Publishing.

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, *16*, 145-163.

Romero, T., Pérez-Baena, I., Larsen, T., Gomis-Tena, J., Loor, J. J., & Fernández, C. (2020). Inclusion of lemon leaves and rice straw into compound feed and its effect on nutrient balance, milk yield, and methane emissions in dairy goats. *Journal of Dairy Science*, *103*(7), 6178-6189.

Samiaji, T. (2012). Karakteristik gas N2O (Nitrogen Oksida) di atmosfer indonesia. *Berita Dirgantara*, *13*(4), 144-154.

Susilawati, H. L., & Pramono, A. (2021, February). Quantifying the potency of greenhouse gas emission from manure management through anaerobic digester in Central Java. In *IOP Conference Series: Earth and Environmental Science* (Vol. 648, No. 1, p. 012111). IOP Publishing.

Shan, Y., Guan, D., Liu, J., Mi, Z., Liu, Z., Liu, J., ... & Zhang, Q. (2017). Methodology and applications of city level CO2 emission accounts in China. *Journal of Cleaner Production*, *161*, 1215-1225.

Surmaini, E., Runtunuwu, E., & Las, I. (2011). Upaya sektor pertanian dalam menghadapi perubahan iklim. *Jurnal Litbang Pertanian*, *30*(1), 1-7.

Swastika, D. K. S. (2011). Membangun kemandirian dan kedaulatan pangan untuk mengentaskan petani dari kemiskinan. *Jurnal Pengembangan Inovasi Pertanian*, *4*(2), 103-117.

Syarifuddin, H., Sy, A. R., & Devitriano, D. (2019). Inventarisasi Emisi Gas Rumah Kaca (CH4 dan N2O) Dari Sektor Peternakan Sapi Dengan Metode Tier-1 IPCC di Kabupaten Muaro Jambi: Inventory of Greenhouse Gas Emissions (CH4 and N2O) From the Livestock Sector Using IPCC Tier-1 Method in Muaro Jambi Regency. *Jurnal Ilmiah Ilmu-Ilmu Peternakan*, *22*(2), 84-94.

Tabari, H. (2020). Climate change impact on flood and extreme precipitation increases with water availability. *Scientific reports*, *10*(1), 1-10.

Umemiya, C., White, M., Amellina, A., & Shimizu, N. (2017). National greenhouse gas inventory capacity: An assessment of Asian developing countries. *Environmental Science & Policy*, *78*, 66-73.

Umemiya, C., Ikeda, M., & White, M. K. (2020). Lessons learned for future transparency capacity building under the Paris Agreement: A review of greenhouse gas inventory capacity building projects in Viet Nam and Cambodia. *Journal of Cleaner Production*, *245*, 118881.

Wahyudi, J. (2017). The Determinant Factors of Biogas Technology Adoption in Cattle Farming: Evidences from Pati, Indonesia. *International Journal of Renewable Energy Development*, *6*(3), 235.

Wahyuni, S., & MP, S. (2011). *Menghasilkan Biogas dari Aneka Limbah (Revisi)*. AgroMedia.

Zuratih, Z., Budhi, S. P. S., & Bachruddin, Z. (2020). Condition of Rumen Fermentation as Impacted by Supplementation of Fermented Rice Brand Using In Vitro Gas Production Technique. *Jurnal Ilmu Ternak dan Veteriner*, *25*(2), 74-80.