Comparison of methane production from cattle, buffalo, goat, rabbit, chicken, and duck manure

C Hidayat¹, Y Widiawati¹, B Tiesnamurti², A Pramono³, R Krisnan¹ and M I Shiddieq²

¹Indonesian Research Institute for Animal Production, Ciawi, Indonesia
²Indonesian Center for Animal Research and Development, Bogor, Indonesia
³Indonesian Agricultural Environment Research Institute, Pati, Indonesia

E-mail: hidayat_c2p@yahoo.com

Abstract. Livestock manure is reported to be one source of methane (CH₄) emission. The objective of this study was to measure methane production from several types of livestock manure. The experiment used a completely randomized design (CRD), with 6 kinds of livestock manure (cow, buffalo, goat, rabbit, chicken, and duck). Each treatment was repeated three times during 8 weeks. The research method used to measure methane production was a closed chamber method, with intervals of 5 minutes. Methane samples were analyzed using gas chromatography. The results of the study showed that during eight weeks of observation, the kinds of livestock manure significantly (p<0.05) affected methane production at weeks 3, 6, 7, and 8. In those weeks, duck manure produced the highest methane production compared to other manure. Total methane gas production during 8 weeks observation which produced by duck manure was 97.99 mg g⁻¹. Meanwhile, the lowest methane produced by rabbit manure (2.70 mg g⁻¹). The study concluded that duck manure produced the highest methane, conversely, rabbit manure produced the lowest methane. The characteristics of fresh manure determine the level of methane production from manure. Making biogas is the best effort in mitigating methane from manure.

1. Introduction
Some gases could trap infrared heat from the Earth’s surface and increase the temperature of the Earth in a manner similar to a greenhouse [1, 2]. Therefore, these gases called Greenhouse Gases (GHG). The livestock sector accounts for approximately 18% of global anthropogenic GHG emissions [3]. Direct GHG emission from livestock comes from two activities, i.e., livestock digestion (enteric fermentation) and manure management [4]. Indirect GHG emission comes from feed production, land clearing, production and marketing of livestock products [1]. Livestock manure is one of the methane emission sources [4]. The main components of livestock manure are water and organic matter. In anaerobic conditions, the anaerobic bacteria will decompose organic matter and release methane [5].

The amount of methane emissions from livestock manure is related to the management of livestock manure [6]. Livestock manure management is closely related to methane gas emissions because it is related to the factors that cause methane emissions, namely oxygen content, water content, pH and nutritional content of livestock manure [6]. Some of the factors that have been reported to cause the amount of methane emission from livestock manure are temperature, pH, humidity, and type of feed [4]. Conditions that support methane gas emissions from livestock manure are high temperature (>39°C), high humidity and neutral pH [7]. Methane emissions from manure are higher when livestock are in large numbers and are penned, which normally manages the manure in the liquid system. The
decomposition of solid feces and urine under aqueous conditions results in higher methane emissions. Handling of manure in solid or pastured form results in lower methane emissions [8].

Methane is one of the responsible gases against global warming and ozone depletion, at a rate of 1% per year and increasing [9]. Due to the higher potential for global warming by methane gas production, methane emissions from livestock manure must be minimized or maximized for further gas use (biogas). Methane production from livestock manure, if managed properly, can be a source of energy. Animal manure can be used to produce biogas [10]. The utilization of methane production from livestock manure as an energy source by making it biogas, is not only beneficial for the environment, but also increases the economic value of livestock manure [11, 12]. Methane is the main component in biogas which makes biogas flammable [13]. Therefore, the aim of this study is to calculate the methane production from several types of livestock manure (cattle, buffalo, goat, rabbit, chicken, duck).

2. Materials and methods
This research was conducted in the methane laboratory of the Indonesian Research Institute for animal production, Ciawi-Bogor-Indonesia. This experiment used a completely randomized design with treatment of 6 types of livestock manure (cattle, buffalo, goat, rabbit, chicken, and duck), each type of manure was given 3 replications. Observations were made for 8 weeks. The tools used were a tube-shaped gas extraction hood, a 25 ml syringe, vial, and gas chromatography. The materials used include 18 chambers (figure 1), thermometer, three way tap and vial 10 ml, to store gas samples, and gas standard for CH₄. Chambers were made from locally available materials namely PVC. The chamber size was 30 cm high and 15 cm in diameter. The study used 6 different types of livestock manure (cows, buffalo, goats, rabbits, chickens, and ducks) with an average weight of 1500 g fresh weight. Each commodity has 3 replications (chamber).

![Figure 1. Chamber used to measure methane emissions from livestock manure.](image)

On the first day after the manure is put into the chamber, gas was taken from the chamber, with the following procedure; the chamber was closed, then the thermometer was installed at the top of the chamber. The hole for taking gas was closed with a rubber cap. Gas samples were then taken at 5, 10, 15, 20, 25 minutes after the chamber was closed. Before taking gas samples, the temperature on the thermometer installed in the chamber was recorded. After taking the last gas (25th minute), the lid of the chamber was opened again. When gas sampling was not taken, the chamber was left open. This was done to condition the chamber in aerobic conditions.

To describe the manure handling in the farmer. The gas extraction was carried out every week until the 8th week. It was assumed that after a period of 8 weeks the manure had dried, indicating that the decomposition process had been completed. The number of gas samples put into the vial must exceed the capacity of the vial capacity to make the pressure in the vial negative. For example; the vial capacity was 10 ml, then the gas that was entered is about 20 ml. The gas-filled vial was taken from the chamber.
and then sent to Indonesian Agricultural Environment Research Institute to be analyzed for methane content.

The parameter observed was the weekly production of methane. Methane gas samples were analyzed using Gas Chromatography (GC) type GHG-450 variant. The results of the gas sample analysis were calculated to be methane gas production/emission using the following formula [14].

\[
E = \frac{dc}{dt} \times \frac{V_{ch}}{A_{ch}} \times \frac{mW}{mV} \times \frac{273.2}{(273.2 + T)}
\]

Explanation:
- \( E \) : \( \text{CH}_4 \) emissions (mg m\(^{-2}\) day\(^{-1}\))
- \( \frac{dc}{dt} \) : Difference in \( \text{CH}_4 \) concentration per time (ppm/minute)
- \( V_{ch} \) : Chamber volume (m\(^3\))
- \( A_{ch} \) : Chamber area (m\(^2\))
- \( mW \) : Molecular weight of \( \text{CH}_4 \) (g)
- \( mV \) : The volume of the \( \text{CH}_4 \) molecule (22.41 l)
- \( T \) : Average temperature during gas sampling (°C)

The average methane production data in each week of each type of manure was analyzed using Analysis of Variance (ANOVA). In the observed week, if the treatment had a significant effect (P < 0.05), then a further test was carried out with the Duncan test using SAS 9.1.2 software.

3. Results and discussion

Based on table 1, it can be seen that the methane gas production for 8 weeks of observation for each type of livestock manure. The amount of methane from different type of manure in week 1, 2, 4 and 5 are the same (P > 0.05). While at week 3, 6, 7 and 8, the amount of methane are significantly different (P < 0.05). At those 4 weeks, duck manure produced the highest methane production compared to livestock manure from other livestock types. The production of methane for livestock manure other than ducks shows an insignificant difference. Total methane for 8 weeks for all types of livestock manure produced duck manure as the largest methane producer (97.99 mg g\(^{-1}\)), followed by livestock manure from buffalo (21.93 mg g\(^{-1}\)), cow (20.32 mg g\(^{-1}\)), chicken (17.88 mg g\(^{-1}\)), goat (6.01 mg g\(^{-1}\)), and finally, rabbit (2.70 mg g\(^{-1}\)). The characteristics of duck manure, which contain more water than other livestock manure, are thought to be an important and significant factor in the level of methane production. High water content will affect the temperature and humidity conditions in the chamber. This is inversely proportional to the characteristics of livestock manure from rabbits which have dry conditions, resulting in lower methane production. This result is different from previous reports which state that the largest production of methane from livestock manure (chicken, cow, and goat) is produced from livestock manure from cows as the largest methane producer [15]. Among three types of manure (cattle, chicken, goat). In general, fresh cattle manure contains a higher water content than chicken and goat manure. Therefore, this is the reason for the higher production of methane for cattle manure compared to chicken and goat manure in that study.

One of the factors that influence methane production is temperature. Temperature affects decomposing microorganisms in the anaerobic fermentation process. In this study, the temperature range in the chamber was in the range of 24 to 27°C. The process of decomposing organic matter by microorganisms during the acidification stage produces acetic acid which will be broken down in the methanogenesis stage, one of which becomes methane. Bacteria perform the highest activity at a temperature range of 35°C to 55°C, above that temperature the activity decreases so that the bacteria do not have activity both in their growth and in the production of acetic acid [16]. The optimum working temperature for methane gas production is 35°C and anaerobic digestion can take place in the temperature range of 5°C to 55°C [17]. The highest total production of methane gas under mesophilic conditions and in a longer retention time. The yield of methane gas under thermophilic conditions was
higher only in the first ten days of methane gas production [18]. pH is also one of the factors that influence methane gas production. High methane production occurs in the pH range 6-8 and the highest production occurs at pH 7 [19]. The optimum pH value for anaerobic fermentation is 5.5 to 8.5. Excessive increase in acid can inhibit methanogens [20].

Table 1. Methane production from several types of livestock manure for 8 weeks of observation.

| Types of manure | Methane production (mg g⁻¹ day⁻¹) | Total 8 weeks (mg g⁻¹) |
|-----------------|------------------------------------|-------------------------|
|                 | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 |                     |
| Cow             | 0.353  | 0.996  | 0.366a | 0.665  | 0.316  | 0.128b | 0.055b | 0.02b  | 20.32b              |
| Buffalo         | 0.122  | 0.881  | 0.031b | 0.646  | 1.078  | 0.144b | 0.204b | 0.025b | 21.93b              |
| Goat            | 0.069  | 0.019  | 0.237b | 0.111  | 0.092  | 0.08b  | 0.167b | 0.08b  | 6.01bc              |
| Rabbit          | 0.059  | 0.031  | 0.034b | 0.079  | 0.046  | 0.084b | 0.027b | 0.023b | 2.70b               |
| Chicken         | 0.394  | 0.598  | 0.12b  | 0.427  | 0.209  | 0.232b | 0.418b | 0.154b | 17.88bc             |
| Duck            | 0.094  | 0.79   | 0.778a | 0.301  | 2.74   | 7.168a | 1.516a | 2.216a | 97.99a              |
| SEM             | 0.054  | 0.15   | 0.082  | 0.107  | 0.28   | 0.733  | 0.1     | 0.178  | 5.82                |
| p-value         | 0.300  | 0.237  | 0.028  | 0.435  | 0.079  | 0.0121 | 0.0017 | <0.001 | <0.001              |

Different superscripts on the same line were significantly different (p <0.05).

Methane generated from livestock manure varies depending on the type of feed given, physiological status and faecal handling management [4]. High-nutrient feed types tend to produce low amounts of methane such as concentrate feed, whereas forage feeds high in crude fiber [21]. The availability of organic matter and anaerobic conditions produce methane in livestock manure through methanogens [22]. Another report also reported the same thing, that the type of feed consumed by livestock, especially the content of organic matter and fiber affects the amount of methane gas production [23]. Nutrients released in feces become the raw material for methane production. The organic material in feces can be used by methanogenic bacteria to produce methane. The higher the organic matter content in the feces will increase the production of methane produced [24]. The fermentation process of organic matter that occurs in livestock manure also affects the production of methane produced. The fecal fermentation process is able to produce methane due to the presence of methanogenic bacteria in the feces and remodel the C component in feces to produce methane. In addition to the total content of organic matter, organic C content also plays a role in the production of gas produced. The higher the organic C which is degraded, the higher the methane produced [25]. The chemical composition of manure depends on the animal’s diet and environmental conditions. Manure consists of water and organic matter [26]. The pH and NH₄⁺ content of livestock manure affects the production of methane produced [27]. One of the other factors that influence methane gas production is climate (temperature and rainfall), and manure management [28]. With the methane production data from this research, it can be estimated that methane production from each type of manure per unit weight within a certain period of time. So it can be estimated methane emission from each type of manure. Efforts to mitigate methane emissions from livestock manure are to make it a renewable energy source (biogas) [29]. The use of livestock manure to become biogas, not only reduces greenhouse gas emissions but also becomes a potential source of alternative energy in the future. Thus, biogas can help reduce the use of fossil energy sources [30].

4. Conclusions

During 8 weeks of observation on six types of livestock manure (cow, buffalo, goat, rabbit, chicken, and duck), it was concluded that total livestock manure from ducks produced the largest methane gas production and livestock manure from rabbits produced the smallest methane gas production. The
characteristics of fresh manure determine the level of methane production from manure, especially the water content in the manure. Making biogas is the best effort in mitigating methane from manure.

References
[1] Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M and de Haan C 2006 livestock’s long shadow: environmental issues and options [Cited 2020 July 15] Available from: http://www.fao.org/3/a0701e/a0701e00.htm
[2] United States Environmental Protection Agency (US-EPA) 2010 Methane and nitrous oxide emissions from natural sources office of atmospheric programs [Cited 2020 July 17] Available from: https://www.epa.gov/gmi
[3] Weiss F and Leip A 2012 Greenhouse gas emissions from the eu livestock sector: a life cycle assessment carried out with the CAPRI model Agriculture, Ecosystems and Environment 149: 124-134
[4] Lascano C E and Cárdenas E 2010 Alternatives for methane emission mitigation in livestock systems R. Bras. Zootec 39: 175-182
[5] Environmental Protection Agency (EPA) 1999 US Methane Emissions 1990 - 2020: Inventories, projections, and opportunities for reductions; US Environmental Protection Agency [Cited 2020 July 15] Available from: https://www.epa.gov/gmi
[6] Intergovernmental Panel on Climate Change (IPCC) 1996 Greenhouse gas inventory reporting instructions Revised IPCC Guidelines for National Greenhouse Gas Inventories [Cited 2020 July 15] Available from: https://www.ipcc.ch/report/revised-1996-ipcc-guidelines-for-national-greenhouse-gas-inventories/
[7] Bull P, McMillan C and Yamamoto A 2005 Michigan Greenhouse Gas Inventory 1990 and 2002 [Cited 2020 July 15] Available from: http://css.umich.edu/publication/michigan-greenhouse-gas-inventory-1990-and-2002
[8] Carlsson-Kanyama A and González A D 2007 Non-CO2 Greenhouse Gas Emissions Associated with Food Production : Methane (CH4) and Nitrous oxide (N2O), Kungliga Tekniska Högskolan, Sweden Livestock of Urban Agriculture in Beijing Agriculture Ecosystem and Environment 170 : 28-35
[9] Suryahadi A R, Nugraha A, Bey and Boer R 2002 Methane conversion rate and methane emission factor in buffalo fed with local tape yeast with different levels containing Saccharomyces cerevisiae Summary of the Postgraduate Program Seminar IPB University Bogor-Indonesia.
[10] Recebli Z, Selimli S, Ozkaymak M and Gonç O 2015 Biogas production from animal manure Journal of Engineering Science and Technology 10 (6): 722-729
[11] Amankwah E 2011 Integration of biogas technology into farming system of the three northern regions of Ghana J. Econ. Sust. Develop 2:76-85
[12] Sakhawat A, Naseem Z, Zahida N and Shumaila U 2013 Impact of biogas technology in the development of rural population Pakistan J. Anal. Environ. Chem. 14:65 – 74
[13] Prabhudessia V, Salsaonkar B, Braganca J, and Mutnuri S 2014 Pretreatment of cottage cheese to enhance biogas production [Cited 2020 July 15] Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4065734/pdf/BMRI2014-374562.pdf
[14] IAEA (International Atomic Energy Agency) 1993 Manual on measurement of Methane and Nitrous Oxide Emission from agricultural [Cited 2020 July 19] Available from: https://inis.iaea.org/collection/NCLCollectionStore/_Public/24/019/24019160.pdf
[15] Jacob J H, Al Fawwaz A T and Al Shirah H H 2018 Evaluation and Optimization of Methane Production from Different Manure Types Jordan Journal of Biological Sciences 11 (3) : 323-327
[16] Darmanto A, Soeparman S and Widhiyanurliawan D 2012 Effect of Mesophilic (35°C) and Thermophilic (55°C) Anaerobic Horse Manure Digester Conditions on Biogas Production Journal of Mechanical Engineering 3(2): 317-326
[17] Ratnaningsih, Widyatmoko H and Yananto T 2009 The Potential of Biogas Formation in the Biodegradation Process of a Mixture of Fresh Organic Waste and Cow Manure in an Anaerobic Reactor Batch *Trisakti University Journal* 5 (1): 20-26
[18] Rashed M B 2014 The Effect of Temperature on the biogas Production from Olive Pomace *ISSUE* 3 (16)
[19] Budiyono, Pratiwi M E and Sinar I N 2013 Effect of Fermentation Method, Feed Composition, Initial pH, and Dilution Variations on Biogas Production from Vinasse *Journal of Chemical Research* 9 (2): 1-12
[20] Verma S 2002 *Anaerobic Digestion of Biodegradable Organics in Municipal Solid Wastes* [Internet] [Cited 2020 July 19]. Available from: http://gwcouncil.org/m-s-thesis-anaerobic-digestion-of-biodegradable-organics-in-municipal-solid-wastes/
[21] Bamualim A M, Thalib A, Anggraeni Y N and Mariyono 2008 Beef cattle farming technology that environmentally friendly *Wartozoa* 18 (3):149-156
[22] Riddle W C, Kebreab E, France J, Clark K and Rapai J 2005 *Supporting Measurements Required for Evaluation of Greenhouse Gas Emission Models for Enteric Fermentation and Stored Animal Manure* [Cited 2020 July 19] Available from: https://pdfs.semanticscholar.org/89d6/e047292be1cc13e3d6227ca397cf56151a81.pdf
[23] Haryanto B and Thalib A 2009 Methane emissions from enteric fermentation: its contribution nationally and the factors affecting it in livestock *Wartozoa* 19 : 157 - 165
[24] Hakim L N, Nurwantoro and Purnomoadi A 2012 Total anaerobic bacteria, gas production and bio-digester gas production rate by adding rice husks to raw materials for beef cattle feces *Anim Agric J* 1 : 342 – 351
[25] Puspitasari R, Muladno, Atabany A and Salundik 2015 Methane (CH₄) Gas Production from Lactating Dairy Cow Feces with Elephant Grass and Rice Straw Diet *Journal of Animal Production Science and Technology* 3 (1): 40-45
[26] Flynn H, Smith P, Bindi M, Trombi G, Oudendag D and Rousseva S 2007 Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT) [Cited 2020 July 20] Available from: https://cordis.europa.eu/project/id/44148
[27] Park K H, Thompson A G, Marinier M, Clark K and Wagner-Riddle C 2006 Greenhouse gas emissions from stored liquid *Atmos Environ* 40:618-627
[28] Jun P, Gibbs M and Gaffney K 1996 CH₄ and N₂O emissions from livestock manure, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories [Cited 2020 July 20] Available from: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_2_CH4 and_ N2O Livestock_Manure.pdf
[29] Leip A, Ledgard S, Uwizeye A, Alhares J C P, Aller M F, Amon B, Binder M, Cordovil C M D S, De Camillis C and Dong H 2019 The value of manure-Manure as co-product in life cycle assessment *J Environ. Manag.* 241: 293-304
[30] Daniel-Gromke J, Rensberg N, Denysenko V, Stinner W, Schmalfuß T, Scheftelowitz M, Neljes M and Liebetrau J 2018 Current Developments in Production and Utilization of Biogas and Biomethane in Germany *Chem. Ing. Tech.* 90: 17-35