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# Greenhouse gas emissions from livestock manure (cattle) in different feeding formulas, methods and practices

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**Abstract**

The United Nations Food and Agriculture Organization (UNFAO) reported that the livestock sector generates more greenhouse gas emissions with 18% of the total $CO_2$ emissions, 3% higher than the transport sector with 15%. Thus, urgent action is needed to mitigate the emission of greenhouse gasses from livestock. The study used twenty-four (24) heads of cattle (eight natives, eight crossbreeds, and eight Brahman). These test animals were distributed in the four experimental treatments: treatment 1- commercial feeding practices, treatment 2- good agricultural practices, treatment 3- conventional feeding practices, and treatment 4- organic agricultural practices. The result shows that conventional feeding practice had the lowest greenhouse gas emission with an average emission of 1,996.37 L, while good agricultural practice is the highest (3,614, 59 L) and is a significant difference among treatment means ($p = >0.05$). With regards to the breeds of cattle, crossbreeds had the lowest greenhouse gas emissions (2,030.87 L) while Brahman was the highest (3,312.42 L) with no significant difference ($p = >0.05$). Moreover, gas chromatography analysis shows methane had the highest percent emission (52-72%), followed by carbon dioxide (16.33-18.33%) and other gasses (11-22%). The findings revealed that feeding practices affect the emission and composition of greenhouse gasses in cattle manure.

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## Introduction

Global warming seriously affects the agroecological, flora and fauna growth conditions and agricultural production (Rosegrant *et al.,* 2007; Aydinalp & Cresser, 2008), and greenhouse gasses (GHG) are a significant contributor to climate change. Agriculture has been identified as a prominent source of anthropogenic greenhouse gas emissions (Anita *et al.,* 2010), and livestock gas emissions are one of these. According to FAO (2015), the livestock sector contributes about 75 percent of agricultural nitrous oxide ($N_2O$) emissions, with an equivalent of 2.2 billion tons of carbon dioxide ($CO_2$). Besides, livestock is a significant driver of the global trends in land utilization and changes in land use, including deforestation and desertification. According to the United Nations Food and Agriculture Organization, the livestock sector generates more greenhouse gas emissions measured in $CO_2$, with 18% compared to the transport sector. Moreover, according to Steinfeld *et al.* (2006), livestock is one of the most substantial contributors to today's most dangerous environmental problems.

Livestock contributes to climate change by emitting GHG directly through enteric fermentation and manure management or indirectly through feed-production activities and forest conversion into the pasture. The life cycle assessment (LCA) approach estimated that the livestock sector emits about 7.1Gt of $CO_2$-eq or about 18% of global anthropogenic GHG emissions. Moreover, LCA estimated that chemical fertilizer in livestock feed emitted about 0.4 Gt of $CO_2$-eq. Furthermore, enteric fermentation in ruminants contributed 1.9 Gt $CO_2$-eq of GHG, while manure management accounted for 2.2 Gt $CO_2$-eq. These cover manure storage, application, and deposition ($CH_4$, $N_2O$) (Steinfeld *et al.*, 2006). In 2015, the livestock sector contributed approximately 75 percent of the agricultural nitrous oxide ($N_2O$) (2.2 billion tons of $CO_2$) emissions and 2.7 billion tons of carbon dioxide ($CO_2$) emissions.

Most livestock animals are ruminants, and cattle are one of those. Ruminant has a unique digestive system that allows them to use the energy from fibrous plant material efficiently. In the ruminant's digestive system, methane emission is a natural part of its digestive process (enteric fermentation). Also, Methane gas is a by-product of manure management operations in ruminants. Ruminants account for up to one-third of the anthropogenic methane ($CH_4$) emissions worldwide (Huhtanen *et al.*, 2014). In 2011, the United States emitted about 137 million metric tons of methane (in $CO_2$ equivalents) from the enteric fermentation of livestock, comprising about 70% of the total agricultural methane emissions. Beef cattle are by far the most significant species contributor of enteric methane. Beef cattle contribute nearly 100 million metric tons of $CO_2$ equivalents annually in the U.S., nearly three (3) times that of dairy cattle and 50 times greater than swine (Smith, 2014). On the other hand, a software called HOLOS, a farm model developed by Agriculture and Agri-Food in Canada, revealed that enteric methane ($CH_4$) accounted for 63 percent of the total GHG emissions. Also, cattle manure was recorded with the highest nitrous oxide ($N_2O$) at 23 percent (Beauchemin *et al.,* 2010).

In early 1991, the Philippines started its efforts to address the issue of climate change. From 1990 to 1994, the Philippines launched its national greenhouse gas emissions inventory. The agricultural and forestry sectors have integrated into their development plans measures on greenhouse gas mitigation through the Philippine Clean Air Act of 1999 (Merilo, 2001).

The implementation of the Philippine Clean Air Act of 1999 becomes the venue for the implementation of other environmental policies such as the Asia Least-Cost Greenhouse Gas Abatement Project (ALGAS), National Action Plan on Climate Change and the "Enabling Activity on Climate Change." However, more than these endeavors are needed to mitigate GHG emissions. In 1990, the Philippines recorded 96Mt of carbon dioxide ($CO_2$) emissions; in 2018, it increased to 159 Mt of carbon dioxide. It is garnering an average of 139 Mt of carbon dioxide ($CO_2$) and an average of 0.31% of the total global shares, which leads the Philippines to rank 6$^{th}$ in Southeast Asia (Ilea, 2006).

The continuing increase of GHG emissions despite the existing law leads to the birth of the "Greenhouse Gas Emission Atmospheric Removal Act of 2015" and "Low Carbon Economy Act of 2016". These acts hoped to minimize GHG emissions by setting up an emission cap-and-trade system in the industry sector and facilitating the development, demonstration, and implementation of technology that shall remove GHGs from the atmosphere (Merilo, 2001). However, with the increasing economic growth and population, the demand for meat and dairy products is increasing yearly. Global meat production is projected to double from 229 million tons in 1999/2001 to 465 million tons in 2050, while milk output is set to climb from 580 to 1043 million tonnes. Hence, the need to balance production and mitigate GHG emissions from cattle is undeniably vital. That is why this study was conducted to determine the relationship between feeding methods and practices and the volume of GHG in decomposing manure.

## Materials and methods

*Setting up the Experiment*

Twenty-four (24) heads of cattle were used in the study, which was composed of eight (8) native breeds, eight (8) crossbreeds, and eight (8) Brahman. The animals were divided into four experimental treatments. Each treatment had six (6) cattle with two (2) replications of cattle (one male and one female) per breed. The animals were treated with four different feeding methods and practices as follows: Treatment 1-Commercial feeding practices with 60% concentrate feeds (rice bran, copra meal, ground yellow corn, molasses, and salt), 40% types of grass (Napier grass and corn fodder) and Urea Molasses Mineral Block (UMMB) as a food supplement. Treatment 2-Good agricultural practices with 10.25kg of rice bran, 0.33kg of Ipil-ipil, and salt (per 100kg of cattle). Treatment 3 - Conventional farming, wherein the animals are tethered in a pasture area and fed with concentrates (39% Rice bran, 69% Copra meal, and 1% salt) and grasses (Napier grass/Para grass/Guinea and Leguminous grasses, free of choice) and Treatment 4-Organic agricultural practices and range type pasture with no antibiotic and growth hormone. In this treatment, cattle were given rice bran (1.5% of cattle body weight) mixed with indigenous microorganisms (IMO), salt, and grasses (Napier grass/para grass/ guinea). Randomized Complete Block Design (RCBD) was employed in this study.

*Experimental Animals*

Before the administration of treatments, the experimental animals were subjected to clinical pathology tests such as Elisa Caprine Arthritis Encephalitis (CAE) Virus, Brucella test, Surra CATT test, and Fecalysis test. The experimental animals' initial body weight was determined using a digital scale. The initial weight was used to calculate the number of feeds given to the test animals and a reference in calculating the test animals' gained weight.

*Administration of Feeding Practices*

Feeding materials were administered for 90 days (April 25, 2018- July 25, 2018). The administered feeding materials were weighed before and after feeding (leftover) to calculate the test animals' feed intake.

*Manure Collection* A

The manure collection used a tailored fit harness attached to the test animals. The manure was then stored in a customized gas digester for 60 days to measure the volume of the greenhouse gasses from the cattle manure.

*Gas Chromatography Analysis*

Collected accumulated gas samples were adequately labeled according to treatment codes and were securely packed inside a polyethylene drum. The samples were submitted to the Philippine Institute of Pure and Applied Chemistry (PIPAC), Ateneo de Manila University (ADMU), for gas chromatography analysis. This analysis determines the percent composition of methane ($CH_4$), carbon dioxide ($CO_2$), and other gasses.

*Data Analysis*

Weight gain, feed efficiency, percent apparent digestibility, and volume of emitted greenhouse gasses were the data analyzed.

Gain weight was calculated by subtracting the final gained weight from the initial body weight of the cattle. On the other hand, feed efficiency is calculated by dividing the total feed consumption by the total gained weight. Moreover, the percent apparent digestibility was calculated by dividing the total feed intake by fecal output and multiplying by 100. The measurement of the emitted volume of greenhouse gasses from the decomposing manure was determined through the Torus formula: V=22Rr2. Where *V is* the volume of gas, *R* is the radius of the torus, and *r* is the radius inside the torus. Moreover, Pearson correlation r was used to determine the relationship between feed efficiency, apparent digestibility, gained weight, and volume of emitted greenhouse gasses. Furthermore, Tukey's HSD test was used to determine if there is a significant difference among the treatment mean using the SPSS software version 15.

## Results and discussion

*The volume of Greenhouse Gas Emissions*

The findings on the average volume of greenhouse gas emissions show that conventional feeding practices had the lowest emission of greenhouse gasses (1,996.37L), followed by organic agricultural practices (2,084.51L). In contrast, good agricultural practices had the highest emission (3,614, 59L) (table 1).

However, no significant differences among treatment mean (p *>0.05*). The type of concentrates and roughages can be attributable to factors affecting the GHG emission volume among the treatment means. The result implies that the nutritional components of feeding materials (roughage and concentrates) are the possible factors in the GHG emission variation affecting the production of gasses during rumen fermentation. Regarding breeds, crossbreed cattle obtained the lowest volume of GHG emission (2,030.87 L), while Brahman cattle had the highest (3,312.42L). However, no significant difference was recorded (p>*0.05*).

The findings imply that cattle breeds' morphology and rumen physiology did not influence the volume of the emitted greenhouse gas.

**Table 1.** The average volume of GHG emission of livestock cattle (L).

| Treatments | Native (e) | Crossbreed (f) | Brahman (g) | Mean [ns] |
|---|---|---|---|---|
| (a) Commercial Feeding Practices | 3,172.55 | 2,053.50 | 2,218.09 | 2,481.38 |
| (b)Good Agricultural Feeding Practices | 1,983.24 | 2,141.02 | 6,719.50 | 3,614.59 |
| (c)Conventional Feeding Practices | 1,991.27 | 1,961.19 | 2,036.66 | 1,996.37 |
| (d )Organic Feeding (d) Practices | 2,010.34 | 1,967.76 | 2,275.44 | 2,084.51 |
| Mean[s] | 2,289.35 | 2,030.87 | 3,312.42 | 2,544.21 |

Legend: Having the same letter has no significant difference among treatments means a 5% significance level.

*Percentage Composition of GHG*

Gas chromatography analysis revealed that the test animals emitted 52-72 percent of methane, 16.33-18.33 percent of carbon dioxide, and 11-22 percent of other gasses across the four feeding practices. Moreover, a significant difference was recorded in the percent methane and other gasses ($p < 0.05$), as shown in Fig.s 1 and 3. The finding implies that GHG emissions differed in each treatment, and the type of feeding practices and method applied possibly affected the rumen fermentation that affects methanogens and other bacteria present in the rumen in the production of gasses. However, no significant differences among treatment means of carbon dioxide, as shown in fig. 2.

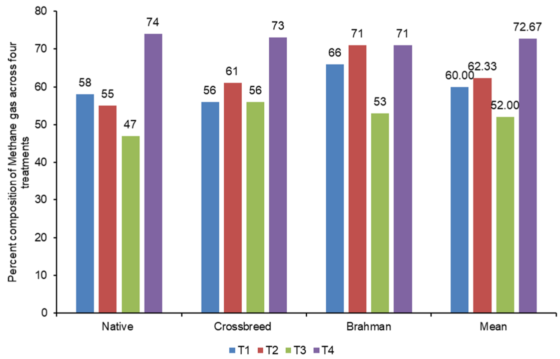


**Fig. 1.** Percentage composition of Methane gas in four feeding methods and practices.

Legend: T1- Commercial Feeding Practices, T2- Good Agricultural Practices, T3- Conventional Feeding Practices, T4- Organic Feeding (D) Practices.

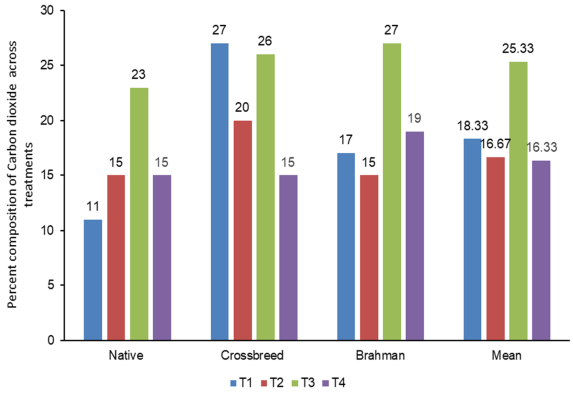


**Fig. 2.** Percentage composition of Carbon dioxide gas in four feeding methods and practices. Legend: T1- Commercial Feeding Practices, T2- Good Agricultural Practices, T3- Conventional Feeding Practices, T4- Organic Feeding (D) Practices.

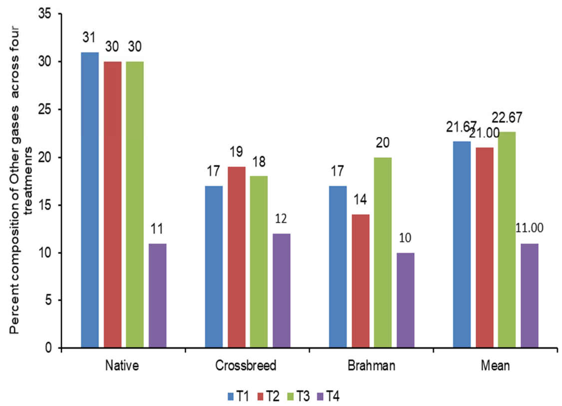


**Fig. 3.** Percentage composition of other gas in four feeding methods and practices. Legend: T1- Commercial Feeding Practices, T2- Good Agricultural Practices, T3 - Conventional Feeding Practices, T4- Organic Feeding (D) Practices.

The study's findings revealed that feeding methods and practices could affect the emission level of methane, carbon dioxide, and other gasses, as observed in the results of the organic agricultural practices and conventional feeding practices. According to Hammond *et al.* (2016), the methane emission per unit intake in dairy cows was associated with changes in the efficiency of fiber digestibility. The effect of diets such as intake and composition accounted for a large proportion of variation in enteric methane emissions from dairy cows (Mills *et al.*, 2003). They identified that essential components influencing methane emissions are fermentable carbohydrates, fiber, fat, and digestible energy intake (Bell *et al.*, 2012). These findings supported the study's results wherein organic and good agricultural practices had the highest percent methane, with 72.67 percent and 62.33 percent, respectively. Both organic agricultural and good agricultural practices' feed composition are rich in fiber, and the majority is from the grasses, resulting in a much higher dry matter intake of cattle compared to commercial and conventional feeding practices. Also, Eckert *et al.* (2018) found that increasing dry matter intake increased methane emissions by 0.02 mg/L per kilogram of dry matter intake. The differences in emissions among farms are explained primarily by factors associated with changes in individual feed intake over time. Increasing the forage content of the diet is known to increase ruminal acetate production, which promotes methane production (Jouany, 2008).

These are possible reasons why conventional and commercial feeding practices had the highest percentage of carbon dioxide. Organic dairy cows receive more fiber-rich hay that produces relatively more methane than conventional dairy cows with concentrates which produce relatively less methane (Warnecke *et al.* 2014).

The study concluded that organic dairy cows produce slightly more methane from enteric fermentation per kilogram of feed consumed than conventional dairy cows. Further, diets high in concentrates are easy to digest and lower the rate of neutral detergent fiber degradation in the rumen. The higher methane and hydrogen production per kilogram of DMI reflect more enteric gas relative to feed intake, indicating a more intense fermentation in the rumen that favors hydrogen production rather than consumption. Furthermore, according to Oljhoek *et al.* (2018), the average low-concentrated diet produces a higher average of methane per kilogram at 21.3kg compared to a highly concentrated diet with 17.8.

On the contrary, cattle treated with a high-concentrate diet had an increase in carbon dioxide ($CO_2$) production and oxygen consumption. These results coincide with the results of the percent carbon wherein conventional and commercial feeding practices had the highest percent carbon with 25.33% and 18.33%, respectively.

*Correlation Analysis between Growth Performance, Feed Efficiency, Apparent Digestibility, and Volume of Gas Emission*

Correlation analysis revealed a strong negative linear correlation between feed efficiency and cattle gained weight (*r* =-0.817) and significantly different (*p* = 0.001). This result implies that when the value of feed efficiency is low, the higher amount of body weight gain. Moreover, the correlations between the average volume of gas and feed efficiency have a strong negative correlation (*r* = -0.53) but are not significantly different. However, a weak positive correlation (*r* =0.257) was noted between the percent apparent digestibility and cattle gain weight. In contrast, the correlation between percent apparent digestibility and feed efficiency have a weak negative correlation (*r* = -0.288), and both have no significant difference (fig. 4).

Feed efficiency is associated with profitability, as feed efficiency refers to the capacity to convert feeds into body weight (Shike, 2013), meaning feed efficiency and gain weight are inversely proportional, as manifested in the results of the correlation analysis. The results of the correlation analysis also supported the findings on the feed efficiency and gained weight. Among the four treatments, commercial feeding practices have the highest weight gain (45.90, table 2) and the lowest feed efficiency simultaneously (51.98, Table 3).

**Table 2.** Average gained weight of cattle under different feeding methods and practices (Kg).

| Treatments | Native (e ) | Crossbreed (f) | Brahman (g) | MEAN* |
|---|---|---|---|---|
| (a)Commercial Feeding Practices | 45.50 | 54.00 | 38.19 | 45.90 (c) |
| (b)Good Agricultural Feeding Practices | 39.21 | 33.42 | 15.98 | 29.54 (b) |
| (c)Conventional Feeding Practices | 20.85 | 13.50 | 16.78 | 17.04(a) |
| (d)Organic Feeding Practices | 6.41 | 12.03 | 8.72 | 9.05(a) |
| Means | 27.99 | 28.24 | 19.92 | 25.38 |

Legend: Having the same letter has no significant difference among treatment means @ a 5% significance level.

**Table 3.** Average feed efficiency of cattle under different feeding methods and practices.

| Treatments | Native (e) | Crossbreed (f) | Brahman (g) | Mean |
|---|---|---|---|---|
| (a)Commercial Feeding Practices | 85.86 | 23.75 | 46.32 | 51.98(a) |
| (b)Good Agricultural (b) Feeding Practices | 38.39 | 44.62 | 100.36 | 61.13(b) |
| (c)Conventional Feeding Practices | 54.78 | 157.92 | 100.12 | 104.28(b) |
| (d) Organic Feeding Practices | 235.14 | 202.77 | 176.02 | 204.65(c) |
| Means | 103.55 | 107.27 | Mean | 103.55 |

Legend: Having the same letter has no significant difference among treatment means at a 5% significance level.

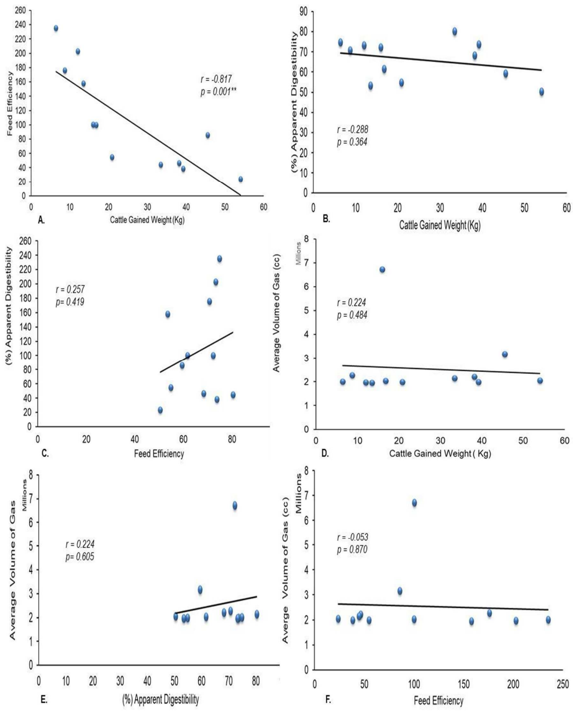


**Fig. 4.** Correlation analysis between (A) feed efficiency and cattle gained weight, (B) apparent digestibility and cattle gained weight, (C) apparent digestibility and feed efficiency, (D) average volume of gas and cattle gained weight, (E) average volume of gas and apparent digestibility and (F) average volume of gas and feed efficiency.

Based on the correlation analysis between the volume of gas and feed efficiency, there was a negative correlation with a value of (r= -0.57). The result implies that feed efficiency decreases when the value of the gas volume increases.

These findings corroborate Yan *et al.* (2010) that the attribute of energy-efficient cows is a lower methane production relative to energy intake or milk production. Also, breeding for cattle with high feed efficiencies might lead to a decline in daily enteric methane production due to the positive genetic and phenotypic correlation between daily methane production and residual feed intake (Nkrumah *et al.*, 2006; de Haas *et al.,* 2011).

*Waste management technology as a mitigating measure in GHG emission*

The indigenous microorganism (IMO), bio-char, and carbonated rice hull (CRH) were tested to mitigate the volume of GHG emission. A ratio of 1:12 for every 1kg of IMO, bio-char, and CRH was added to the 12kg manure sealed in a container allowing anaerobic fermentation. As shown in Table 4, applying the indigenous microorganism to native cattle in a conventional feeding method decreases GHG emissions by 37,773 ml.

**Table 4.** The volume of GHG emission treated with indigenous microorganisms, bio-char, and carbonated rice hull.

| Treatments | Native (e) (IMO) | Crossbreed(f) (Bio-char) | Brahman(g) (CRH) | Mean |
|---|---|---|---|---|
| (a)Commercial Feeding Practices | 2,508.62 | 2,169.94 | 2,228.87 | 2,302.48 |
| (b)Good Agricultural Practices | 8,864.01 | 2,166.45 | 4,099.62 | 5,026.69 |
| (c) Conventional Feeding Practices | 1,953.76 | 2,386.89 | 2,319.50 | 2,220.05 |
| (d) Organic Feeding Practices | 3,465.88 | 1,987.90 | 1,965.87 | 2,473.22 |
| Mean$^{s}$ | 4,198.07 | 2,165.29 | 2,653.46 | 3,005.61 |

Legend: Having the same letter has no significant difference among treatment means at a 5% significance level.

In addition, the application of carbonized rice hulls to Brahman cattle in good agricultural practices decreases by 309,569.25 ml. However, adding 1kg of CRH to decomposing manure from Brahman cattle in good agricultural practices declines about 38% or 2,619,881.78 ml of GHG.

The reduction of GHG emissions can be due to the physical and chemical properties of the carbonized rice hull that can mitigate the methane gas. However, results revealed no significant differences in treatment means and breed of cattle as far as the volume of GHG emission is concerned. With these, further studies are recommended to quantify the appropriate levels of indigenous microorganisms, biochar, and carbonated rice hull (CRH) as a waste management technique in mitigating GHG emissions from cattle manure and other livestock.

## Conclusion

Based on the findings of the study, the following conclusions can be drawn: The feeding formula in each treatment affects the volume of greenhouse gas emissions (methane, carbon dioxide, and other gasses). Regardless of breed and treatment, no significant difference was observed regarding pf volume of GHG emission. Applying indigenous microorganisms in the conventional feeding system decreases GHG emissions, and based on the findings of the correlation analysis, it shows that gaining weight is associated with feed efficiency.

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