Enteric methane emission and growth rate of three different breeds of beef cattle fed on oil palm frond or grass basal diet

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Abstract. Enteric methane emission in ruminants is affected by the feed quality. The study aimed to evaluate the performance and enteric methane emission of three beef cattle breeds fed on grass or oil palm frond basal diet. The study used three cattle breed, namely Bali, Ongole crossbred, and PO crossbred. The cattle were fed on grass or oil palm frond (OPF) basal diet and supplemented with concentrate based on palm kernel cake (PKC). Diet was fed in total mixed ration contained 12% crude protein. The study was conducted in a randomized block design in a 3x2 factorial arrangement. Results showed that the growth rate, dry matter digestibility, and enteric methane emission were not affected (P>0.05) by the interaction of cattle breed and basal diet type. No main factor affected (P>0.05) on the parameter observed. The average values of dry matter digestibility, average daily gain (ADG), methane emission, and methane intensity of the cattle were 63.38%, 359 g day−1, 91. L day−1, and 177.32 gCH4 kg ADG−1, respectively. The study indicates that OPF could be used as a basal diet of beef cattle without affecting its performance. Cattle breeds had similar performance either fed on grass or OPF basal diet.

1. Introduction
Livestock is one of the agricultural sub sectors under consideration for its contribution to climate change. The sub sector contributes significantly to climate change from the emissions of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). This contribution either directly (from enteric fermentation or manure management) or indirectly (from feed production activities, conversion of forest into pasture). Among ruminants animals, beef cattle is the most contributors to CH4 emission due to its highest population and big body size. CH4 emission calculated using Tier 2 from beef cattle was 9,850Gg CO2-e/year in 2014 [1]. The beef cattle population expected to increase due to government programs to improve the beef cattle population to achieve domestic beef self-sufficiency. The increase in the beef population will consequently grow GHG emissions. Increasing beef production while maintaining environmental sustainability needs to be considered. It can be achieved through increasing efficiency of resources used.

GHG emissions from the livestock sub-sector are also affected by diet and management systems. Methane is one of the end products from feed fermentation by rumen microorganisms. Enteric microbial fermentation is the primary source in the ruminant emission. Nutrition of the diet affects methane emission. Diet higher in fiber content produced higher acetic acid In contrast, increased concentrate proportion in the diet with low fiber content resulted in a reduction of acetic acid
production and increased propionic amount. Hence methane emission decreased [2]. Acetic acid is hydrogen production, while propionic is hydrogen consumption. In the rumen, the formation of methane depends on both hydrogen gas supply from feed fermentation by bacteria and protozoa, and conversion $\text{H}_2$ and $\text{CO}_2$ by methanogenic bacteria into $\text{CH}_4$. Therefore, dietary strategies are one of the methods for reducing methane emission in ruminants [3].

Many breeds of beef cattle are raised in Indonesia. However, it is required to select beef cattle breed, adaptive to climate change and efficient in utilizing local feedstuff, to reduce enteric $\text{CH}_4$ emission. Different cattle breeds with different diets could be expected to have further different methane production. Other breeds of beef cattle (PO vs. PO x Simental) had other methane production with a similar diet offered [4].

Palm beef cattle integration is one of the applications of efficient resource utilization. Biomass and by-products from palm oil processing and production could be used as a feed source for cattle in the area of oil palm plantation. Oil palm frond (OPF) can be used as a fiber source as grass replacement. Whereas, palm oil extraction produces palm kernel cake and solid decanter, being commonly used as beef cattle feed supplement in smallholder farmers. A complete diet containing palm kernel cake and OPF with the inclusion of OPF in the ration at 25% did not affect the growth of goat [5]. However, the inclusion of PKC at a high percentage level (80%) reduces the growth rate of the goat [6]. Oil palm frond can be used to replace native grass basal diet with palm kernel cake as a supplement without affecting the body weight gain of Bali Cattle [7]. From a previous study, there is a possibility of using by-products from palm oil production as a fiber source or as a concentrate source as cattle feed. Therefore with integrated oil palm and cattle farming systems could be expected to obtain high production of beef cattle and oil palm. Smallholder farmers in Indonesia commonly do this integrated farming. This production system is expected to be sustainable and environmentally friendly. Therefore, it is needed to evaluate the GHG emission, particularly enteric $\text{CH}_4$, from beef cattle raised under the palm-cow and the various beef cattle breed integration system. The study aimed to evaluate the enteric methane emission and growth rate of three different beef cattle breed feed on an oil palm frond or grass basal diet supplemented by concentrate containing palm kernel cake.

2. Materials and methods

2.1. Animal management and feeding experiment

The study was conducted in beef cattle farm station PTPN VI, Jambi. The study used three breeds of beef cattle, namely Bali, Ongole Bred (PO), and Ongole crossbred (PO x Brahman; PX). In each cattle breed was used eight heads of post-weaning male calves with an average body weight of 105.75 ± 12.45 kg; 115.25 ± 15.0 kg, and 103.35 ± 24.75 kg respectively for Bali, PO, and PX. Each breed was divided into two treatment diets, namely different basal diets with chopped elephant grass (EG) and oil palm frond (OPF). Diet treatment composition is presented in Table 1. Diet offered in total mixed ration with ratio forage (OPF or elephant grass) to concentrate 30:70. The concentrate was formulated consisted of cassava waste, rice bran, palm kernel cake, urea, molasses, mineral mixed, and salt. Diets were formulated in iso protein contained crude protein (CP) 11.6%. The study was conducted for four months, consisting of three months of growth trial, two weeks of methane collection, and 1-week digestibility measurement. During the study, the calves were kept in an individual pen.
Table 1. Composition and nutrients content of diet treatment fed to the cattle during experiment.

| Ingredients            | Proportion (%) | Diet treatment |
|------------------------|----------------|----------------|
|                        |                | EG | OPF |
| Elephant Grass (EG)    | 30             | 0  | 0   |
| Oil Palm frond (OPF)   | 0              | 30 | 0   |
| Concentrate            | 70             | 70 | 70  |
| Crude protein (%)      |                | 11.16 | 11.62 |
| Crude fat (%)          |                | 6.93  | 7.19 |
| NDF*                   |                | 67.32 | 65.94 |
| Gross Energy (Cal)     |                | 3,866 | 3,735 |

*NDF = neutral detergent fiber.

2.2. Parameter recorded
Parameters recorded were feed consumption, growth rate, dry matter digestibility, and methane emission. Feed consumption was measured daily by calculating the difference between feed offered and refusal. Daily offered and refusal feeds were weighed in the morning before feeding the cattle. Feed digestibility was measured using the total collection method by daily weighing offered and refusal feeds and excreted fecal for seven days. Feces, feed offered, and feed residues was subsampled (100 g) for seven days and dried in an oven. Growth rates of calves were obtained by monthly weighing in the morning before feeding. Enteric methane emission was measured using a portable headbox respiratory chamber. Gas excreted from respiration was sucked and flew out using a vacuum pump and collected in a plastic bag. The gas collection was done for 10 minutes. The gas volume in the bag was then measured. Gas was then sub-sampled in a vial for the CH₄ concentration measurement using gas chromatography in the Laboratory of Assessment Institute for Agriculture Technology Jambi Province.

2.3. Experimental design and data analysis
The study was conducted in a randomized complete block design in a factorial 3x2 arrangement, three levels of beef cattle breed, and two levels of different basal diet. Each treatment had four replications. Data were analyzed using GLM from SAS software 9.0 [8]. Differences among means were compared using Duncan's multiple range test at 5%.

3. Results and discussion
There was no significant interaction effect between cattle breed and diet (P>0.05). Similarly, no significant main factor effect either from breed or from diet on final body weight or average daily gain (ADG) (P>0.05) with an average of ADG was 374.5 g (Table 2). The average of dry matter intake (DMI) was 2611 g head⁻¹day⁻¹ or about 2.1% of body weight. The feed conversion ratio was also similar between treatment and cattle breed, with an average of 7.78. The previous study showed that Bali cattle fed on an oil palm frond basal diet supplemented with palm kernel cake producing ADG 420 g day⁻¹, which was similar to a grass basal diet supplemented with palm kernel cake [7]. Crossing between local beef cattle breeds such as PO and exotic cattle breeds such as Limousin, Simental, and Angus has been introduced in Indonesia with the purpose of increasing productivity of beef cattle. However, many factors affected their productivity, such as the ability to digest local feed sources, particularly fiber sources which are commonly from crop by-products such as rice straw, corn stover, and oil palm frond. The increased production of crossbred cattle usually resulted from increased DMI.
Other studies reported that elephant grass diet supplemented with concentrate 0.75% fed to PO or PL (PO x Limousin) resulted in DMI of PO cattle 2.1% and DMI PL cattle 2.99% of BW [4].

Table 2. Initial body weight (IBW), final body weight (FBW), average daily gain (ADG), and feed conversion ratio (FCR) of different breed fed on elephant grass or oil palm frond basal diet.

| Breed | Basal Diet | Parameter | IBW (kg) | FBW (kg) | ADG (g day$^{-1}$) | FCR  |
|-------|------------|-----------|----------|----------|---------------------|------|
| Bali  | EG         |           | 104.0    | 137.0    | 418.0               | 6.77 |
|       | OPF        |           | 107.0    | 138.0    | 390.0               | 6.96 |
| PO    | EG         |           | 104.75   | 132.75   | 350.0               | 7.73 |
|       | OPF        |           | 114.5    | 139.4    | 310.9               | 10.47|
| PX    | EG         |           | 102.0    | 140.25   | 478.2               | 6.51 |
|       | OPF        |           | 102.5    | 126.6    | 301.5               | 8.26 |

Significance

| Main factor | Basal diet x basal diet | NS | NS | NS | NS |
|-------------|-------------------------|----|----|----|----|

Note: EG = elephant grass; OPF = oil palm frond; NS = nonsignificant (P>0.05); PO = Ongole crossed; PX = PO crossed with Brahman.

The ADG obtained were 310g and 410 g, with FCR 6.6 and 7.5 respectively each for PO and PL. Results from the current study were comparable to the previous researches [4,7]. Other findings reported that improved breed AN (Nellore x Angus) had a similar growth rate to Nellore (local breed) when both breed were raised under tropical pasture [9]. However, when the cattle were raised in feedlot feeding, improved cattle breed (AN) has higher average daily gain indicating that improved breed should be managed in a better management system to increased their productivity. In the present study, cattle were fed on OPF or elephant grass basal diet with CP content 11%. This could be the reason that the diet was not able to meet the requirement of PX to increase the productivity of PX cattle. These results also indicated that improved breed required appropriate conditions to express their potential productivity.

Dry matter digestibility (DMD) of the cattle was not affected by the interaction between cattle breed and diet (P>0.05) and was not affected by the main factor effect of breed and by basal diet (Table 3). A similar DMD was expected since the diet was formulated in similar protein content and the NDF content. The average DMD was 63.32%. Methane emission was also identical in all beef cattle breed fed on different basal diet. The average of enteric methane emission was 91.69 L day$^{-1}$ or 65.65 g day$^{-1}$. Enteric methane production was affected by fiber content in the diet; the higher the fiber content, the higher the methane emission (9). In this study, fiber content (NDF) was similar between the grass and OPF basal diet; therefore, methane production was identical. Methane production (L day$^{-1}$) or methane intensity (g CH$_4$ kgADG$^{-1}$) shows no significant difference (P>0.05). The average methane intensity was 177.32 gCH$_4$ kgADG$^{-1}$. Similar to this study, Maciel et al. [9] reported that methane emission of the different breed was not significantly different in producing gCH$_4$ kgADG$^{-1}$ was 119.53 and 140.03 gCH$_4$ kgADG$^{-1}$ respectively for Nellore and Nellore x Angus. The higher CH$_4$ intensity of the current study compared the results from Maciel et al. [9] could be caused by differences in the quality of the diet. In the other study showed that the pasture had CP content 12.7% and supplemented by supplement with CP content 22% [9], while in this study, the diet as total mixed ration with CP content 11%. It shows that a better quality diet will result in better digestibility. The increase in feed quality and digestibility could reduce methane emission as much as 30% [10]. On the other hand, the higher methane production per ADG of PO and PL (PO x Limousin), which were 208 and 220 gCH$_4$ kgADG$^{-1}$ in diet elephant grass basal diet supplemented by concentrate at 0.75% of BW.
was reported by Purnomoadi [4]. From current study shows that the local beef cattle breed (Bali and PO) was similar in producing methane per kg ADG than that of PX (PO x Brahman) fed on elephant grass or oil palm frond basal diet. Therefore, OPF combined with palm kernel cake and other agricultural by-products can be used to formulate a diet to support sustainable beef cattle production and environmentally friendly.

Table 3. Dry matter intake (DMI), dry matter digestibility (DMD), CH4 production, and CH4 intensity of different beef cattle fed the different basal diet.

| Breed | Basal Diet | Parameter                  | DMI (g day⁻¹) | DMD (%) | CH4 production (L day⁻¹) | CH4 intensity (gCH4 kgADG⁻¹) |
|-------|------------|----------------------------|---------------|---------|--------------------------|----------------------------|
| Bali  | EG         |                            | 2,795.05      | 65.37   | 85.89                    | 147.12                     |
|       | OPF        |                            | 2,580.82      | 58.67   | 113.4                    | 208.19                     |
| PO    | EG         |                            | 2,378.00      | 61.50   | 76.77                    | 157.04                     |
|       | OPF        |                            | 2,743.10      | 62.52   | 76.90                    | 177.10                     |
| PX    | EG         |                            | 2,785.10      | 68.72   | 106.9                    | 160.05                     |
|       | OPF        |                            | 2,389.05      | 63.14   | 90.30                    | 214.44                     |

Significance

Main factor

Basal diet

Interaction breed x basal diet

Note: EG = elephant grass; OPF = oil palm frond; ADG = average daily gain; NS = nonsignificant; PO = Ongole crossed; PX = PO crossed with Brahman.

4. Conclusions

From this study, it can be concluded that oil palm frond could be used as basal diet replacing grass without affecting growth rate, dry matter digestibility, and methane emission of the cattle. Bali, PO, or PO crossbred cattle had similar performance either fed on grass or oil palm frond basal diet.

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References

[1] Widiawati Y, Rofiq M N and Tiesnamurti B 2016 Methane emission factors for enteric fermentation in beef cattle using IPCC Tier-2 method in Indonesia Indonesian J. Anim. Vet. Sci. 21 101-111

[2] Duthie C A, Haskell M, Hyslop J, Waterhouse A, Wallace R J, Roche R and Rooke J A 2017 The impact of divergent breed types and diets on methane emissions, rumen characteristics and performance of finishing beef cattle Animal 11 1 doi:10.1017/S1751731117000301

[3] Martin C, Morgavi D P and Doreau M 2010 Methane mitigation in ruminants: from microbe to the farm scale Animal 4 351-365

[4] Purnomoadi A 2014 Emisi metan pada ternak ruminansia dan hijauan potensial rendah emisi metana Potensi bahan pakan local untuk menurunkan gas metana ternak ruminansia (in Bahasa) ed Tiesnamurti B, Nurhayati, Herawati T, Widiawati Y and Yulistiani D vol 2 (Jakarta: IAARD press) pp 18-36
[5] Ebrahimi M, Rajion M A, Meng G Y, Shokryzadan P, Sazili A Q and Jahromi M F 2015 Feeding oil palm (Elaeis guineensis, Jacq.) fronds alters rumen protozoal population and ruminal fermentation pattern in goats Ital. J. Anim Sci. 14 403-409

[6] Abubakr A R, Alimon A R, Yaakub H, Abdullah N and Ivan M 2013 Growth, nitrogen metabolism and carcass composition of goats fed palm oil by-products Small Rum. Res. 112 91-96

[7] Nanda D D, Purnomoadi A and Nuswantara L K 2014 Penampilan produksi sapi bali yang diberi pakan dengan berbagai level pelepah sawit (in Bahasa) Agromedia 32 54-63

[8] SAS 2002 Guide for Personal computers (NC USA : SAS Institute Cary)

[9] Maciel I C dF, Barbosa F A, Tomich T R, Ribeiro L G P, Alvarenga R C, Lopes L S, Malacco V M R, Rowntree J E, Thomson L R and Lana A M Q 2019 Could the breed composition improve performance and change the enteric methane emissions from beef cattle in a tropical intensive production system? PLoS ONE 14 e0220247 https://doi.org/10.1371/journal.pone.0220247

[10] Wang T, Teague W R, Park S C and Bevers S 2015 GHG Mitigation Potential of Different Grazing Strategies in the United States Southern Great Plains Sustainability 7 13500-13521