Agronomy Research **24**(1), 427–434, 2026
https://doi.org/10.15159/AR.26.026

Estimation of enteric methane emissions from crossbred beef cattle in Vietnam: a case study in Quang Ngai province

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Received: February 2nd, 2026; Accepted: April 24th, 2026; Published: May 8th, 2026

Abstract. The objective of this study was to estimate methane (CH_4) emissions from four crossbred cattle groups commonly raised in Vietnam: ½ Belgian Blue cattle (BBB × Lai Brahman), ½ Charolais cattle (Charolais × Lai Brahman), ½ Droughtmaster cattle (Droughtmaster × Lai Brahman), and ½ Red Angus cattle (Red Angus × Lai Brahman), from 6 to 18 months of age ($n = 4$ per group). All animals were fed the same diet and monitored for feed intake and weight gain. Gross energy intake was calculated, and enteric CH_4 emissions were estimated using the Tier 2 methodology of the Intergovernmental Panel on Climate Change. Dry matter intake, live weight, and enteric CH_4 emissions (kg month^{-1}) increased with age in all groups. The highest values were observed in ½ Charolais, followed by ½ BBB, ½ Red Angus, and ½ Droughtmaster. However, emission intensity (kg CH_4 kg^{-1} carcass weight or kg CH_4 kg^{-1} edible protein) was significantly lower in ½ BBB and ½ Charolais compared to ½ Red Angus and ½ Droughtmaster ($P < 0.001$). Total enteric CH_4 emissions over the 13-month period averaged 67, 69, 61, and 64 kg for ½ BBB, ½ Charolais, ½ Droughtmaster, and ½ Red Angus, respectively. It is concluded that crossbreeding strategies that improve animal productivity can reduce enteric CH_4 emission intensity per unit of product.

Key words: crossbreeding, methane emission, enteric fermentation, beef cattle, emission intensity, Vietnam.

INTRODUCTION

In Vietnam, ruminant production, particularly cattle farming, is playing an increasingly important role in agricultural development. As of June 2022, the national cattle population exceeded 6.41 million head, of which more than 5.99 million were beef cattle, representing a 1.3% increase compared to 2021 (GSO, 2022). In 2021, beef consumption reached 8.4 kg per capita per year and is projected to increase to 9.6 kg per capita per year by 2029. However, domestic production currently satisfies only about 50% of the total demand, with the remainder supplied through imports.

Quang Ngai province is one of the leading provinces for cattle production in Central Vietnam and nationwide. In 2018, the proportion of crossbred cattle in Quang Ngai reached 70.6%, exceeding the averages of the Central region (60%) and the national level (59%) (GSO, 2018). Various crossbreeding systems have been widely adopted, including crosses of Charolais cattle, Belgian Blue cattle (BBB), Droughtmaster cattle, and Red Angus cattle with Lai Brahman cows (a crossbred between Yellow local cattle and Brahman). Previous studies have shown that these crossbred cattle exhibit superior growth performance, achieving average daily gains of 0.7–0.9 kg head^{-1} day^{-1} during the growing phase and 1.0–1.2 kg head^{-1} day^{-1} during the finishing phase under smallholder conditions in Central Vietnam, with carcass yields ranging from 42% to 49% (Hang et al., 2022; Thao et al., 2023). This performance is significantly higher than that of local cattle breeds in the region (Dung et al., 2013; 2019). These findings indicate that the introduction of high-yielding breeds and their crossbreeding with local cattle has substantially improved productivity.

However, it remains unclear whether these productivity gains are associated with improvements in environmental performance, particularly enteric methane emission - a greenhouse gas. Sahoo et al. (2021) reported that livestock contributes 100–120 kg of metahne per year which is a total of 2,300–2,760 kg of CO_2eq. Worldwide, there are about 1.5 billion cattle and all of them emmit about 87 million metric tons of methane per year. According to the IPCC's Tier 1 estimation method (2006), enteric methane emissions of beef cattle in 2024 in Vietnam are approximately 276.6 thousand tons (equivalent to 7.7 million tons of CO_2eq). With Vietnam's commitment to achieving net-zero emissions by 2050, finding solutions to reduce greenhouse gas emissions in various sectors, including livestock production, is an urgent necessity. The amount of enteric methane emitted by cattle depends primarily on feeding and their productivity. Within the scope of this study, the objective was to estimate enteric methane emissions from high-yielding crossbred cattle in Central Vietnam.

MATERIALS AND METHODS

Animal, diet, and experimental design

The experiment was conducted using a completely randomized design with four crossbred cattle groups: ½ Belgian Blue cattle (BBB × Lai Brahman cow), ½ Charolais cattle (Charolais × Lai Brahman cow), ½ Droughtmaster cattle (Droughtmaster × Lai Brahman cow), and ½ Red Angus cattle (Red Angus × Lai Brahman cow). Each group consisted of four 6-month-old bulls. Initial body weights (mean ± SD) were 181.5 ± 19.5, 192.5 ± 2.86, 168.4 ± 20.56, and 173.4 ± 4.00 kg for ½ BBB, ½ Charolais, ½ Droughtmaster, and ½ Red Angus, respectively.

The experiment lasted 13 months and was divided into two periods: a growing phase (10 months) and a finishing phase (3 months). During the growing phase, cattle were fed concentrate at 1.2% of body weight (BW), which was increased to 1.5% of BW during the finishing phase. In both phases, cattle were additionally offered elephant grass at 0.5% of BW, while rice straw was provided *ad libitum*. The concentrate diet consisted of rice bran, wet brewer's grains, peanut shells, and maize meal. The ingredient composition and chemical characteristics of the concentrate, as well as those of rice straw and elephant grass, are presented in Table 1. The cattle are raised individually, each cattle in its own 4.5 m^2 (1.8m × 2.5m) pen, so the pens are made of cement and have no bedding.

Feed intake was recorded daily, and live weight was measured monthly. Animals were weighed at 06:00 h before morning feeding. At the end of the experiment, all cattle were slaughtered to determine carcass weight, lean meat yield, and edible protein content.

Estimation of enteric methane emission factor

The enteric CH_4 emission factor (EF) was calculated based on gross energy (GE) intake and the methane conversion factor (Ym), following the guidelines of the Intergovernmental Panel on Climate Change - IPCC (2006), using the following equation:

$$EF = \frac{GE \cdot \left[\frac{Y_m}{100}\right] \cdot 30}{55.65} \quad (1)$$

where EF is the methane emission from enteric fermentation (kg CH_4 animal^{-1} month^{-1}), GE is the gross energy intake (MJ head^{-1} day^{-1}), Y_m is the methane conversion factor (% of GE intake converted to CH_4). In the present study, Y_m was assumed to be 6.5%. The constant 55.65 (MJ kg^{-1} CH_4) represents the energy content of CH_4, and 30 is the number of days per month, as CH_4 emissions were estimated on a monthly basis throughout the experimental period.

Total enteric CH_4 emissions over the entire experimental period (13 months) were calculated as the sum of monthly emissions. Methane emissions were also expressed in terms of carbon dioxide equivalents (CO_2-eq) using a conversion factor of 25 (IPCC, 2006).

Table 1. Ingredient composition and chemical characteristics of the concentrate, rice straw, and elephant grass used in the experiment

Items	Concentrate	Elephant grass	Rice straw
Growing phase (6–15 months of age)			
Ingredient (% DM basis)			
Rice bran	30	-	-
Wet brewer's gain	40	-	-
Peanut shell	10	-	-
Maize powder	20	-	-
Total	100	-	-
Chemical composition			
DM (%)	37.9	19.2	89.0
CP (%DM)	17.6	10.2	5.20
OM (%DM)	96.2	85.7	90.4
EE (%DM)	7.70	2.72	2.17
NDF (%DM)	34.0	66.9	66.3
ADF (%DM)	24.1	38.8	43.6
GE (Kcal per kg DM)	4,312	4,090	4,043
Finishing phase (16–18 months of age)			
Ingredient (% DM basis)			
Rice bran	30	-	-
Wet brewer's gain	33	-	-
Peanut shell	12	-	-
Maize powder	25	-	-
Total	100	-	-
Chemical conposition			
DM (%)	42.1	19.2	89.0
CP (%DM)	16.1	10.2	5.20
OM (%DM)	96.4	85.7	90.4
EE (%DM)	7.10	2.72	2.17
NDF (%DM)	32.3	66.9	66.3
ADF (%DM)	23.7	38.8	43.6
GE (Kcal per kg DM)	4,332	4,090	4,043

DM: dry matter; CP: crude protein; OM: organic matter; EE: exther extract; NDF: neutral detergent fibre; ADF: acid detergent fibre; GE: gross energy.

Based on the estimated CH_4 emissions and production parameters, including carcass weight, lean meat yield, and edible protein yield, emission intensity (kg CH_4 per kg of product) was calculated.

Statistical analysis

All data were analyzed using SPSS software (version 16.0; IBM SPSS Statistics). Dry matter intake, live weight, and methane emissions were summarized using descriptive statistics over the experimental period. Differences among crossbred cattle groups were analyzed using the General Linear Model (GLM) procedure according to the following model:

$$Y_{ij} = \mu + G_i + e_{ij} \quad (2)$$

where Y_{ij} is the observation for animal j in group i, μ is the overall mean, G_i is the fixed effect of crossbreed group (i = 1, 2, 3, 4), and e_{ij} is the residual error.

When significant effects were detected, mean comparisons were performed using the least significant difference (*LSD*) test. Statistical significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

Dry matter intake increased linearly with age in all animals (Fig. 1). Among the crossbred groups, the highest DM intake was observed in ½ Charolais cattle, followed by ½ BBB, ½ Red Angus cattle, and the lowest in ½ Droughtmaster cattle. Similarly, live weight increased linearly with age across all groups, and the pattern of live weight gain among crossbreeds was consistent with that of DM intake (Fig. 2).

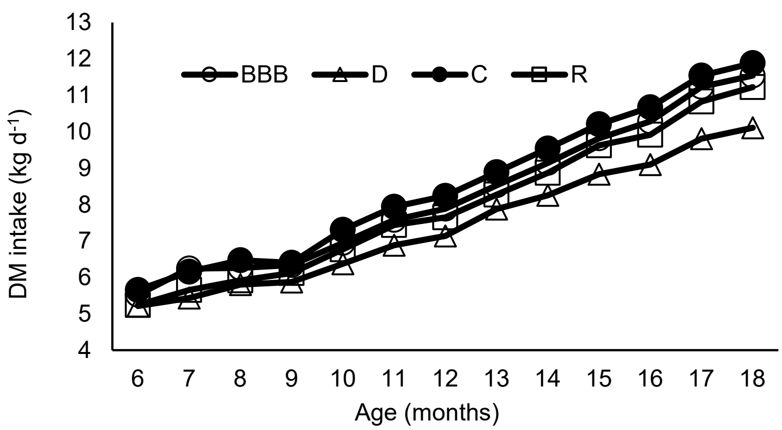

Figure 1. Dry matter intake of crossbred ½ Blue Blanc Belgium (BBB, o), ½ Droughtmaster (D, Δ), ½ Charolais (C, •) and ½ Red Angus (R, □) cattle in Vietnam.

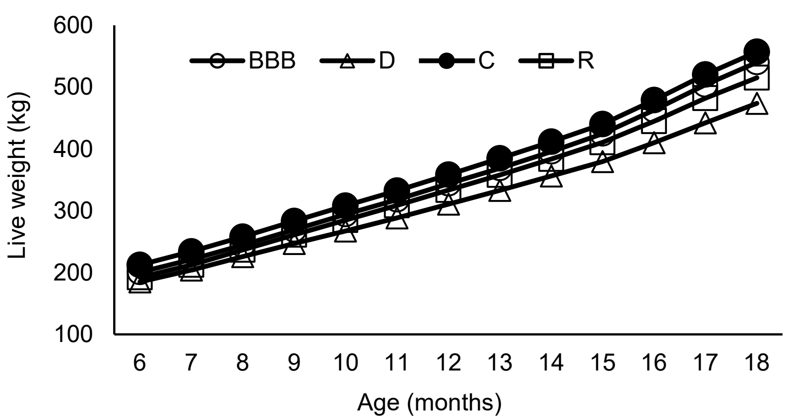

Figure 2. Body growth of crossbred ½ Blue Blanc Belgium (BBB, o), ½ Droughtmaster (D, Δ), ½ Charolais (C, •) and ½ Red Angus (R, □) cattle in Vietnam.

Significant differences among crossbred groups were observed in carcass weight, lean meat yield, and edible protein ($P < 0.001$). Lean meat and edible protein yields did not differ significantly between ½ BBB and ½ Charolais ($P > 0.05$), but were significantly higher than those of ½ Red Angus and ½ Droughtmaster cattle ($P < 0.05$) (Table 1).

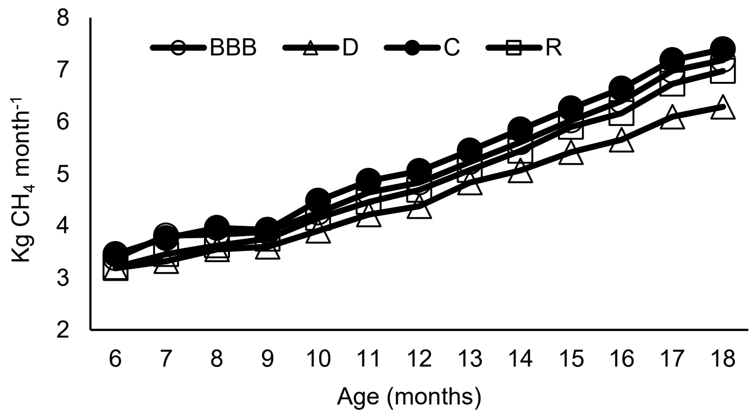

Figure 3. Methane production of crossbred ½ Blue Blanc Belgium (BBB, o), ½ Droughtmaster (D, Δ), ½ Charolais (C, •) and ½ Red Angus (R, □) cattle in Vietnam.

Enteric CH_4 emissions (kg month^{-1}) increased with age in all groups. The highest emissions were recorded in ½ Charolais cattle, followed by ½ BBB, ½ Red Angus, and the lowest in ½ Droughtmaster (Fig. 3). Total enteric CH_4 emissions over the 13-month period averaged 67, 69, 61, and 64 kg for ½ BBB, ½ Charolais, ½ Droughtmaster, and ½ Red Angus cattle, respectively. Emission intensity (kg CH_4 kg^{-1} carcass weight and kg CH_4 kg^{-1} edible protein) was lowest in ½ BBB and ½ Charolais cattle and significantly higher in ½ Red Angus and ½ Droughtmaster cattle ($P < 0.001$), with the highest values observed in ½ Droughtmaster (Table 2).

Methane emissions from the four crossbred cattle groups in this study were higher than those reported by IPCC (2006) for cattle raised in Asia (47 kg CH_4 head^{-1} year^{-1}). This difference may be explained by the higher BW of the crossbred animals used in the present study, which were derived from crosses between tropical cattle and high-producing temperate and tropical breeds.

A clear relationship was observed among feed intake, BW, and methane emissions over time. Across all age groups, methane emissions followed the same ranking as DM intake and live weight: ½ Charolais cattle, ½ BBB, ½ Red Angus cattle, and ½ Droughtmaster cattle. This pattern is consistent with the biological relationship whereby animals with greater BW consume more feed and, consequently, produce higher total methane emissions. Similar findings have been reported by Bond et al. (2019), who showed that daily methane emissions increase with DM intake and rumen volume. This relationship is also supported by Min et al. (2022), who concluded that increased feed intake leads to higher methane emissions.

Improving animal productivity through crossbreeding is considered an effective strategy to reduce methane emissions per unit of product (Lassen & Difford, 2020; Manzanilla-Pech et al., 2021). In the present study, higher-performing crossbred groups

(½ BBB and ½ Charolais) exhibited lower methane emission intensity compared to lower-performing groups (½ Red Angus and ½ Droughtmaster). Methane emissions per unit of product (lean meat or edible protein) were similar within pairs of breeds with comparable productivity (i.e., ½ BBB vs. ½ Charolais, and ½ Red Angus vs. ½ Droughtmaster), likely due to similarities in growth performance and carcass yield.

Table 2. Meat productivity and methane emissions (CH_4) of crossbred ½ Belgian Blue cattle (BBB), ½ Charolais cattle (C), ½ Droughtmaster cattle (D), and ½ Red Angus cattle (R) in Vietnam

Variables	Crossbreeds				SEM	*P*
	BBB	C	D	R		
Animal on feed						
Initial live weight (kg)	182	193	168	173	7.196	0.148
Final live weight (kg)	540^{a}	557^{a}	474^{b}	516^{ab}	10.42	0.001
Carcass weight (CW, kg)	351^{ab}	355^{a}	281^{c}	316^{bc}	8.334	<0.001
Lean meat weight (kg)	265^{a}	259^{a}	204^{b}	219^{b}	6.103	<0.001
Edible protein (kg)	55^{a}	56^{a}	43^{b}	47^{b}	1.342	<0.001
Calculated methane emissions						
Total emissions (kg CH_4 head^{-1} period^{-1})	67^{ab}	69^{a}	61^{b}	64^{ab}	1.790	0.035
Emission intensity (kg CH_4 kg^{-1} CW)	0.19^{a}	0.19^{a}	0.22^{b}	0.20^{c}	0.002	<0.001
Emission intensity (kg CH_4 kg^{-1} lean meat)	0.25^{a}	0.27^{a}	0.30^{b}	0.29^{b}	0.003	<0.001
Emission intensity (kg CH_4 kg^{-1} edible protein)	1.22^{a}	1.23^{a}	1.39^{b}	1.38^{b}	0.027	0.001
CH_4 efficiency (kg CO_2-eq kg^{-1} CW)	4.8^{a}	4.8^{a}	5.4^{b}	5.1^{c}	0.044	<0.001
CH_4 efficiency (kg CO_2-eq kg^{-1} lean meat)	6.3^{a}	6.6^{a}	7.4^{b}	7.3^{b}	0.079	<0.001
CH_4 efficiency (kg CO_2-eq kg^{-1} edible protein)	30.4^{a}	30.8^{a}	34.9^{b}	34.4^{b}	0.674	0.001

[a,b,c] Values within a row with different superscript letter are significantly different ($P < 0.05$); CW: Carcass weight.

Previous studies have reported mixed effects of breed on methane emissions. For example, De Mulder et al. (2018) found that methane emissions per unit of DM intake differed between Holstein-Friesian and Belgian Blue heifers, suggesting a potential influence of the breed on rumen microbial composition. However, Duthie et al. (2017) reported no significant effect of the breed on methane emissions when productivity levels were similar. A meta-analysis by Liu et al. (2017) also indicated that differences in methane emissions among breeds are often driven more by nutritional factors than by breed itself.

Nevertheless, improving productivity has consistently been shown to reduce methane emission intensity (Zhao et al., 2016; 2017; Dewhurst, 2019; Min et al., 2022). As described by Dewhurst (2019), two key mechanisms explain this effect. First, the 'dilution of maintenance' effect means that, at higher production levels, a smaller proportion of feed intake is used for maintenance, thereby reducing emissions per unit of product. Second, higher-producing animals typically have faster feed passage rates through the rumen, reducing fermentation time and methane production.

The total methane emissions (kg per period) observed in this study were lower than those reported for cattle in the Central highland region of Vietnam by Ramírez-Restrepo et al. (2017). However, similar to the present findings, that study also showed that methane emissions increase with animal age. Overall, while high-yielding cattle tend to produce more methane in absolute terms, they exhibit lower methane emissions per unit of product, confirming the importance of productivity improvement as a mitigation strategy. Increasing livestock productivity is a strategy aimed at reducing enteric methane emissions in animal husbandry that has been discussed extensively in previous research (Sahoo et al., 2021; Gebbels et al., 2022). For Vietnam, the results of this study are an important basis for selecting high-yielding cattle breeds, ensuring the achievement of the dual goal of increasing cattle productivity while reducing greenhouse gas emissions, and contributing to ensuring the net-zero emissions target as committed by the Vietnamese Government to the world.

CONCLUSION

Dry matter intake, live weight, and enteric methane emissions (kg month^{-1}) were highest in ½ Charolais cattle, followed by ½ Belgian Blue cattle (BBB), ½ Red Angus cattle, and lowest in ½ Droughtmaster cattle. However, emission intensity (kg CH_4 kg^{-1} carcass weight or kg CH_4 kg^{-1} edible protein) was lower in ½ BBB and ½ Charolais crossbred cattle than in ½ Red Angus and ½ Droughtmaster cattle. These results indicate that although high-yielding cattle produce greater total methane emissions, they reduce methane emissions per unit of product (meat and protein).

ACKNOWLEDGMENTS. The authors wish to thank Hue University for their support under the Core Research Program Grant No. NCTB.DHH.2026.06

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