Prawarun Agr. J. Volume 16(1) 2019, Pages 190–203

Research Article

Growth Performance and Methane Production of Thai Native Beef Cattle under Grazing and Cut-Carry Ruzi Grass with or without Concentrate Supplementation

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Abstract

Despite of concentrate supplements in ruminant diets have been recognized as an influence enteric methane abasement strategy, very few studies have investigated the effects of concentrate supplementation on enteric methane emission under grazing conditions of Thailand. This study aimed to measure growth performance and methane emission from Thai native beef cattle raising under grazing or cut and carry forage with or without concentrate supplementation. Thirty Thai native beef cattle heifers and steers were allocated to a randomized complete block design with six replications. Treatment is feeding systems were continuous grazing in natural pasture: control (T1), rotational grazing in Ruzi grass pasture (T2), cut and carry of Ruzi grass (T3), rotational grazing in Ruzi grass pasture + concentrate (1% of BW) (T4) and cut and carry of Ruzi grass + concentrate (1% of BW) (T5), respectively. Body weight was negative in continuous grazing natural grassland (T1), rotational grazing (T2) and cut-carry Ruzi grass without concentrate supplementation (T3). Continuous grazing natural grassland without concentrate (T1) gave 7.46 %Y_m and was within a range of 6.5±1.0 %Y_m . Thai native beef cattle assigned to confinement systems with cut and carry of Ruzi grass plus 1% body weight concentrate supplementation (T5) released methane of 3.05 %Y_m. Our results suggest that to improve the growth performance and mitigate methane emission of Thai native beef cattle, cut and carry of Ruzi grass with 1% body weight concentrate supplementation should be used.

Keywords: Feeding systems, Grazing, Cut and carry, Methane and Thai native beef cattle

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Prawarun Agr. J. Volume 16(1) 2019, Pages 190–203

สมรรถนะการเจริญเติบโตและการผลิตแก๊สมีเทนของโคเนื้อพื้นเมืองไทยที่ปล่อยแทะเล็มและการตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมและไม่เสริมอาหารข้น

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บทคัดย่อ

ถึงแม้การเสริมอาหารข้นในอาหารสัตว์เคี้ยวเอื้องทราบดีว่าเป็นอีกกลยุทธ์ที่สามารถช่วยลดการผลิตแก๊สมีเทนจากกระบวนการหมักในกระเพาะรูเมนได้ แต่การวิจัยเกี่ยวกับผลของการเสริมอาหารข้นต่อการผลิตแก๊สมีเทนจากกระบวนการหมักในกระเพาะรูเมนของสัตว์เคี้ยวเอื้องภายใต้สภาพปล่อยแทะเล็มในทุ่งหญ้าของประเทศไทยยังมีน้อย ดังนั้นการศึกษานี้จึงมีวัตถุประสงค์เพื่อประเมินสมรรถนะการเจริญเติบโตและการปลดปล่อยแก๊สมีเทนจากโคเนื้อพื้นเมืองไทย ภายใต้ระบบการปล่อยแทะเล็มในแปลงพืชอาหารสัตว์และระบบการตัดไปให้กินที่คอกร่วมกับการเสริมและไม่เสริมอาหารข้น ใช้โคเนื้อพื้นเมืองไทยสามสิบตัวเป็นเพศผู้ตอนและเพศเมียอย่างละสิบห้าตัว สุ่มให้ได้รับระบบการเลี้ยงที่ต่างกันคือ T1 = ปล่อยแทะเล็มในแปลงหญ้าธรรมชาติแบบต่อเนื่อง, T2 = ปล่อยแทะเล็มในแปลงหญ้ารูซี่แบบหมุนเวียน, T3 = ตัดหญ้ารูซี่ไปให้กินที่คอก, T4 = ปล่อยแทะเล็มในแปลงหญ้ารูซี่ร่วมกับการเสริมอาหารข้นให้กินหนึ่ง%ของน้ำหนักตัวต่อวัน และ T5 = ตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมอาหารข้นให้กินหนึ่ง%ของน้ำหนักตัวต่อวัน ตามลำดับ ในแผนการทดลองแบบสุ่มสมบูรณ์ภายในบล็อกใช้โคหกตัวต่อระบบการเลี้ยง พบว่าน้ำหนักตัวของโคในระบบการเลี้ยงแบบปล่อยแทะเล็มในทุ่งหญ้าธรรมชาติอย่างต่อเนื่อง (T1) โคในระบบการปล่อยแทะเล็มแบบหมุนเวียน (T2) และโคในระบบการตัดหญ้ารูซี่ไปให้กินที่คอกไม่เสริมอาหารข้น (T3) ทำให้โคมีน้ำหนักตัวติดลบ การปล่อยโคพื้นเมืองไทยเข้าแทะเล็มแบบต่อเนื่องในทุ่งหญ้าธรรมชาติโดยไม่เสริมอาหารข้น (T1) ให้ค่าอัตราการปลดปล่อยแก๊สมีเทนจากพลังงานรวมที่กินได้ทั้งหมด 7.46 $\%Y_m$ ซึ่งอยู่ในช่วง 6.5±1.0 $\%Y_m$ ตามข้อเสนอของคณะกรรมการระหว่างรัฐบาลว่าด้วยการเปลี่ยนแปลงสภาพภูมิอากาศ ขณะที่โคพื้นเมืองไทยที่ใช้ระบบการเลี้ยงแบบตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมอาหารข้น (T5) ให้ค่าอัตราการปลดปล่อยแก๊สมีเทนจากพลังงานรวมที่กินได้ทั้งหมด 3.05 $\%Y_m$ จากการศึกษานี้เสนอแนะว่าการเลี้ยงโคในระบบการตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมอาหารข้น 1 %ของน้ำหนักตัว สามารถลดปริมาณการปลดปล่อยแก๊สมีเทนและทำให้สมรรถนะการเจริญเติบโตของโคเพิ่มขึ้น

คำสำคัญ: ระบบการให้อาหาร แทะเล็ม ตัดไปให้กิน มีเทน และ โคเนื้อพื้นเมืองไทย

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Introduction

The livestock sector contributes up to 18% of global greenhouse gas emissions and the highest contributors are Asian countries (O' Mara, 2011; Steinfeld *et al*., 2006). Chaokaur (2011) estimated that Thailand released up to 484 billion liters of enteric CH_4 from beef and dairy cattle annually. CH_4 production not only impacts on the environment but it can also reduce both energetic and feed efficiency in cattle (Johnson *et al*., 1994). Many methods of dietary manipulation including forage quality and feed supplementations to mitigate methane production have been reported (Eckard *et al*., 2010; Grainger and Beauchemin, 2011; Hristov *et al*., 2013). In Thailand chamber calorimeter studies have explored enteric CH_4 production from confined Thai native cattle on forage based diets (Chaokaur *et al*., 2015; Chuntrakort *et al*., 2014; Phromloungsri *et al*., 2012). In Thailand 99.94 % of farmers raise their Thai native beef cattle by grazing (Thip-uten, 2019) and/or in confinement or feedlot but there are no recorded methane emission data from grazing cattle to provide a country database. This study aimed to assess growth performance and methane emission from Thai native beef cattle fed by grazing or cut-carry forage with or without concentrate supplementation.

Materials and Methods

This experiment was conducted at Udon Thani Animal Nutrition Development Station, Northeast Thailand from June to October 2014. Average minimum and maximum temperatures ranged from 28 to 37 °C, respectively. The mean rainfall accumulation (January to December 2014) was 1,421.2 mm and minimum and maximum amounts of rainfall were 25.1 and 425.6 mm, respectively (Udon Thani Meteorological Station (UTMS, 2015).

1. Experimental design, feeding management and ingredient composition of concentrate feed

Thirty Thai native beef cattle (*Bos indicus*), 15 of heifers and 15 of steers, with body weights (BW) of 117± 6 kg, and age of 18.5±6 months were allocated in a randomized complete block design with six head (replications) per feeding systems (treatment). The feeding systems were continuous grazing in natural pasture: control (T1), rotational grazing in Ruzi grass pasture (T2), cut and carry of Ruzi grass (T3), rotational grazing in Ruzi grass pasture + concentrate (1% of BW) (T4) and cut and carry of Ruzi grass + concentrate (1% of BW) (T5).

Each treatment had a pasture area of 0.48 ha. Dry cattle manure was applied once at a rate of 12.5 t/ha after cutting height adjustment in May 2014. No cattle manure was applied to T1. The treatment plots had been previously used for organic Ruzi seed production for 8 years (from 2006 to 2014). T1 was in a natural pasture in the same area of the experimental area of the station. The rotational grazing treatment had 6 subplots, 0.08 ha each and 5 consecutive-day grazing. Prior to the trial, all cattle had an adaptation period of 15 days. 1% BW of cut and carry fresh Ruzi and native grasses was fed in the morning and 0.5 kg/head/d of concentrate supplement with rice straw *ad libitum* in the afternoon with free access clean water. Thereafter, the feeding trial was continued for 120 days.

The composition of the concentrate supplement (kg, DM-basis) was as follows: Cassava chip (400), Rice bran (200), Coconut meal (50), Palm kernel cake (50), Kapok seed, (270), Urea (10), Premixed: (Guaranteed analysis: 4,000,000IU/kg Vitamin A, 400,000IU/kg Vitamin D3, 4,000IU/kg Vitamin E, 0.002 g Vitamin B12, 1.00g/kg anti–rancidity, 0.20 g/kg Co, 2.00 g/kg Cu, 0.5 g/kg I, 24.00 g/kg Fe, 16.00 g/kg Mn, 0.05 g/kg Se and 10.00 g/kg Zn; VM–MIX, DVM Intertrade Co. Ltd., Pathumthani, Thailand) (10) and Mineral (10).

2. Animal performance investigations

Each cattle live weight change was monitored monthly using a digital balance. Average daily gain (ADG) of each cattle was calculated by linear regression analysis. Dry matter intake (DMI) (all treatments) and faecal excretion were estimated using a chromium sesquioxide (Cr_2O_3) external marker technique (Coleman, 2005). Dry matter digestibility (DMD) was determined using equations from Schneider and Flatt (1975) and Coleman (2005) with the use of acid insoluble ash (AIA) internal markers with a rectal grab sampling for 5 days consecutively. Concentrate and herbage intake of confinement cattle were obtained from daily records of feed offer and ort. Degradation of organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were calculated according to Schneider and Flatt (1975).

3. Methane emission measurement

Methane (CH_4) gas production was investigated by the Sulfur hexafluoride (SF_6) tracer gas technique (Johnson *et al*., 1994). The SF_6 equipment set consisted of PVC canister, halter, permeation tube and gas chromatography (GC) analyzers. Thirty permeation tubes were charged with SF_6 gas, 0.755 ± 0.067 (mean ± SD) g per tube at -196 °C (liquid nitrogen temperature), weighed and kept at 39 °C. They were weighed daily until steady loss rate was 0.589 mg/day. Thereafter, a permeation tube was placed into the rumen by oral administration and left for 2 weeks before gas measurement. Animals were trained to SF_6 equipment during the equilibration period for one week. Daily eructed CH_4 gas was collected over 5 consecutive days randomly within blocks. For breath and ambient gas samples collection, canisters were prepared by vacuumed status (-95 to -98 kPa) before sampling. PVC canisters with capillary and Teflon tubes were placed to a fitted halter. Gas was collected for a continuous 24 h period with canister change at the same time for the subsequent day. After gas sampling, a successful inner pressure of canister should be -60 kPa. Gas from the canister was transferred to a gas bag using nitrogen gas at 25 kPa. The gas bag samples were analyzed using a GC analyzer. SF_6 gas concentration was analyzed by GC-2014, Shimadzu, Kyoto, Japan with electron capture detector (ECD), 100 m of column, 0.25 mm of inner diameter, 0.2 μm dF; temperature of column oven was 60 °C, carrier gas with 99.9999% of N_2 flow rate at 30 mL/min. Standard gas was 0.1 and 0.5 ppb of SF_6 with N_2 balance. CH_4 concentration was analyzed by GC-8APF, Shimadzu, Kyoto, Japan with a flame ionization detector (FID), packed column with 2.5 m length and inner diameter of 2.6 mm. Temperature of column oven was 170 °C. Carrier gas was 99.9999% of N_2. Standard gas was 200 ppm of CH_4 with N_2 balance (Suzuki, 2015).

4. Gross energy and chemical composition of experimental dietary

Forages and concentrate were sampled monthly, oven dried at 60 °C for 72 h and ground through a 1 mm sieve. The samples were analyzed for gross energy (GE) using IKA-Bomb calorimeter adiabatic (Germany). Ash, ether extract (EE) and CP analyses according to AOAC (1990). NDF and ADF chemical solution were prepared with the method of Van Soest *et al*. (1991) using the applied filter of $ANKOM^{200}$ Fiber analyzer Technology, acid detergent lignin (ADL) according to Van Soest *et al*. (1991), AIA using the method of Van Keulen and Young (1977).

5. Calculation and statistical analysis

ADG was calculated using the linear regression equation: y = a + b(x), where: y = represented weights, x = number of days of experiment, b = ADG for 120-days period and a = intercept of y axis (SAS, 1996).

Feed intake (kg/d) of grazing cattle obtained from feces voided (kg DM/d) ÷ (1-% digestibility of the diet consumed) (Coleman, 2005). Value of feces voided (kg DM/d) was from 100 × kg of external indicator (Cr_2O_3) fed ÷ percentage of external indicator in feces.

Nutrient intake (OM, CP, NDF and ADF) was calculated with the use of DMI (kg) multiply by a component of each nutrient (kg). DMD coefficient was calculated by 100 – [100 × (marker in diet ÷ marker in feces)] according to Schneider and Flatt (1975) and Coleman (2005).

Digestion coefficient of a nutrient (OM, CP, NDF and ADF) was calculated by using formula: 100 – (100 × % AIA in feed × % nutrient in feces) ÷ (% AIA in feces × % nutrient in feed) (Schneider and Flatt, 1975).

GE intake (GEI, MJ/d), digestible energy (DE) intake (DEI, MJ/d) and metabolizable energy (ME) intake (MEI, MJ/d) were determined according to ARC (1980) and McDonal *et al*. (2002) as the following formulae: GEI calculated by GE content of feed (MJ) × DMI (kg/d), DEI obtained from GEI – energy in feces (MJ) × feces excretion (kg DM/d) and MEI obtained from ME content (MJ) of diet multiply by DMI (kg/d).

DE content (kJ/kg DM) of diet was calculated following ARC (1980): DE = [energy intake (kJ) – energy in feces (kJ)] ÷ DMI (kg). ME content (MJ/kg DM) of feed was calculated according to WTSR (2010) equation as ME = (DE × 0.9613) – 1.2276.

Daily enteric CH_4 emission from each animal was calculated according to Johnson *et al*. (1994) using the known permeation rate of SF_6 and the concentrations of SF_6 background and CH_4 in the breath samples using formula: CH_4 (g/d) = SF_6 permeation rate (g/d) × (CH_4 ÷ SF_6). CH_4 conversion energy and mass values using formula: 39.54 kJ/l and 0.716 g/l, respectively according to Kurihara *et al*. (1999).

Data were subjected to covariance (ANCOVA) analysis using the initial weight of each animal (SAS, 1996) and treatment means were compared by Duncan's new multiple range test (Steels and Torrie, 1980) at probability of 0.05.

Results

1. Chemical composition and energy content of concentrate and forage

Chemical composition of concentrate feed are shown in Table 1. OM, CP, EE, NDF, ADF, and ADL values obtained from laboratory analyses were 89.23, 17.76, 10.06, 24.11, 13.57 and 2.24 % of DM, respectively. GE and ME contents were 17.21 and 14.70 MJ/kg DM, respectively.

Forage DM, OM, CP, NDF, ADF, ADL, and AIA were significantly different (P<0.01) among treatments. DM, NDF, ADF, ADL and AIA in T1 were significantly higher than other treatments (T2-T5) (Table 1).

2. Live weight change, nutrient intake, and digestibility

When Thai native steers and heifers were raised with different feeding systems for 120-days period, body weight gain changed significantly (P<0.01) among treatments. Negative live body weight was found in T1 (-8.16 kg), T2 (-1.50 kg) and T3 (-0.34 kg). This led to significantly lower ADG for T1 (-0.054 kg/d), T2 (0.004 kg/d) and T3 (0.057 kg/d) (Table 2).

Nutrient intake (total DMI, OMI, CPI, NDFI, and ADFI) (Table 2) showed significant differences among treatments (P<0.01). OMI, CPI, NDFI and ADFI in non-concentrate supplementation (T1, T2 and T3) were significantly lower (P<0.01) than in supplemented treatments (T4 and T5). However, OMI, NDFI and ADFI in T4 did not show significant difference cf. T3.

Appearance nutrient digestibility (DM, OM, CP, NDF, and ADF) also showed significant differences among treatments (P<0.01). Appearance nutrient digestibility in T5 was significantly lower than the rest except CP and NDF digestibility where T3 was not significantly different from T5.

3. Energy intake and enteric methane emission

Energy intake (GEI, DEI and MEI) was significantly different among treatments (P<0.01). The concentrate supplemented treatments (T4 and T5) had significantly more energy intake (P<0.01) than non-supplemented treatments (T1, T2, and T3) except GEI, DEI, and MEI in T3 was not significantly different from T4 (Table 2).

The results of enteric CH_4 emissions based on units of: liter per kilogram of nutrient (DM, OM, NDF) intake, gram per day, mega joule per day, and methane emission rate (%Y_m) or percentage of enteric CH_4 per GE intake were not significantly different (P>0.05) among treatments.

Our results showed that Thai native beef cattle released CH_4 ranging from 57.30 to 96.50

L/d, 41.03 to 69.09 g/day, 2.26 to 3.81 MJ/d, and 3.05 to 7.46 %Y_m.

CH_4 production in relation to nutrient intake ranged from 13.31 to 31.13, 14.57 to 35.26 and 20.78 to 43.94 L/kg for DMI, OMI, and NDFI, respectively.

Table 1 Chemical composition and energy content of concentrate and forage

Item	Con.	Forage					SEM	P-value
		T1	T2	T3	T4	T5		
Chemical composition, %								
DM	90.43	41.97[a]	30.80[b]	29.09[d]	30.20[c]	29.04[d]	0.19	**
OM	89.23	88.29[e]	89.39[d]	91.56[a]	89.85[c]	91.34[b]	0.21	**
CP	17.76	6.71[c]	8.98[a]	7.11[b]	9.01[a]	7.02[b]	0.12	**
EE	10.06	1.31[c]	1.59[b]	1.22[d]	1.68[a]	1.29[c]	0.11	**
NDF	24.11	70.84[a]	56.51[e]	64.35[b]	57.54[d]	64.06[c]	0.24	**
ADF	13.57	46.18[a]	32.65[e]	40.60[b]	33.30[d]	40.35[c]	0.23	**
ADL	2.24	3.99[a]	2.44[b]	1.68[d]	2.05[c]	1.69[d]	0.12	**
AIA	3.55	6.95[a]	4.05[b]	2.84[d]	3.40[c]	2.66[e]	0.32	**
Energy content, MJ/kg DM								
GE	17.21	16.75	17.05	17.25	17.15	17.25	0.12	ns
DE	-	9.29[c]	11.06[bc]	12.41[b]	14.49[a]	14.38[a]	0.28	**
ME	[1/]14.70	[2/]7.70[c]	[2/]9.40[bc]	[2/]10.70[b]	[2/]12.70[a]	[2/]12.60[a]	0.27	**

Con. = concentrate. Different superscripts within rows indicate significant differences at P ≤ 0.05 of T1 to T5.
ns = non significance, ** $P \leq 0.01$. SEM = Standard error of mean. T1 (control) = continuous grazing in natural pasture (forage species are *Eragrostis diplachnoides* (Steud.) Stapf. 70%, *Imperata cylindrica* 5%, *Brachiaria Ruziziensis* 5%, *Cynodon plectostachyus* 5%, *Panicum maximum* cv. TD58+*Panicum maximum* cv. Common 5%, *Stylonsanthes hamata* 2%, forbs, shrubs and weeds 8% of area). T2 = rotational grazing in Ruzi grass pasture (98%) with 2% of *Stylonsanthes hamata*.
T3 = cut and carry of Ruzi grass (98%) with 2% of weeds. T4 = rotational grazing in Ruzi grass pasture + concentrate.
T5 = cut and carry of Ruzi grass (98%) with 2% of weeds + concentrate.[1/]Obtained from *in vitro* gas production method, calculated from ME (MJ/kg) = 3.5917 + 0.09821%$IVOMD_{24h}$ + 0.1715%EE (Thip-uten and Sommart, 2012).[2/]Calculated from ME (MJ/kg) = (DE x 0.9613) – 1.2276 (WTSR, 2010)

Table 2 Feeding systems vs. live weight, average daily gain, total dry matter intake, nutrient intake, appearance nutrient digestibility, energy intake, and methane emission of Thai native beef cattle

	Feeding systems					SEM	P-value
	T1	T2	T3	T4	T5		
Initial live weight, kg	118.83	119.83	106.67	122.50	122.00	8.77	ns
Final live weight, kg	110.67^{b}	118.33^{b}	106.33^{b}	147.67^{a}	154.33^{a}	4.39	**
Body weight gain (120 days), kg	-8.16^{b}	-1.50^{b}	-0.34^{b}	25.16^{a}	32.33^{a}	4.42	**
Average daily gain, kg/day	-0.054^{b}	0.004^{b}	0.057^{b}	0.239^{a}	0.304^{a}	0.01	**
Feed intake							
Concentrate intake, kg/day	-	-	-	1.01	1.24	-	-
Forage intake, kg/day	2.27^{b}	2.87^{ab}	3.43^{ab}	4.16^{ab}	4.70^{a}	0.61	*
Total Dry matter feed intake							
kg/day	2.27^{c}	2.87^{c}	3.43^{bc}	5.17^{ab}	5.94^{a}	0.64	**
% of body weight	2.43	3.09	3.51	3.91	3.93	0.54	ns
g/kgBW$^{0.75}$	74.83^{b}	93.81^{ab}	108.63^{ab}	131.74^{a}	135.90^{a}	17.02	*
Nutrient intake, kg/day							
OM intake	2.01^{c}	2.57^{c}	3.14^{bc}	4.65^{ab}	5.42^{a}	0.57	**
CP intake	0.15^{b}	0.25^{b}	0.24^{b}	0.55^{a}	0.49^{a}	0.06	**
NDF intake	1.60^{c}	1.62^{c}	2.21^{bc}	2.97^{ab}	3.80^{a}	0.38	**
ADF intake	1.05^{bc}	0.93^{c}	1.39^{bc}	1.72^{ab}	2.39^{a}	0.23	**
Appearance nutrient digestibility, %							
DM digestibility	76.48^{bc}	85.13^{a}	73.06^{c}	80.38^{ab}	67.56^{d}	1.62	**
OM digestibility	79.65^{bc}	88.39^{a}	75.31^{c}	83.39^{b}	70.43^{d}	1.64	**
CP digestibility	72.22^{bc}	85.21^{a}	63.93^{cd}	79.60^{ab}	59.07^{d}	3.33	**
NDF digestibility	78.62^{bc}	83.75^{a}	74.71^{cd}	80.02^{ab}	70.88^{d}	1.61	**
ADF digestibility	74.17^{ab}	76.93^{a}	70.31^{b}	71.86^{ab}	63.18^{c}	1.89	**
Energy intake, MJ/day							
GEI	37.51^{c}	49.15^{c}	59.13^{bc}	88.75^{ab}	102.46^{a}	11.01	**
DEI	30.29^{c}	43.56^{c}	54.46^{bc}	78.12^{ab}	89.08^{a}	8.92	**
MEI	20.23^{c}	30.86^{c}	37.63^{bc}	65.23^{ab}	76.35^{a}	9.88	**
Methane emission							
L/day	62.82	57.30	73.51	96.50	67.80	10.70	ns
L/kg DMI	31.13	20.54	19.76	22.23	13.31	5.50	ns
L/kg OMI	35.26	22.97	21.58	24.72	14.57	6.21	ns
L/kg NDFI	43.94	36.33	30.73	38.66	20.78	8.24	ns
g/day	44.98	41.03	52.63	69.09	48.54	7.66	ns
MJ/day	2.48	2.26	2.90	3.81	2.68	0.42	ns
%Y_m	7.46	3.37	4.54	5.12	3.05	1.26	ns
Fecal excretion							
kg of DM/day	0.52	0.41	0.30	0.73	0.87	0.19	ns
kg of Nitrogen/day	0.078^{b}	0.091^{ab}	0.093^{ab}	0.11^{a}	0.10^{a}	0.006	*

Different superscripts within rows indicate significant differences at P ≤ 0.05. ns = non significance, * *P* ≤ 0.05, ** *P* ≤ 0.01. Standard error of mean (SEM). T1 (control) = continuous grazing in natural pasture (forage species are *Eragrostis diplachnoides* (Steud.) Stapf. 70%, *Imperata cylindrica* 5%, *Brachiaria Ruziziensis* 5%, *Cynodon plectostachyus* 5%, *Panicum maximum* cv. TD58+*Panicum maximum* cv. Common 5%, *Stylonsanthes hamata* 2%, forbs, shrubs and weeds 8% of area). T2 = rotational grazing in Ruzi grass pasture (98%) with 2% of *Stylonsanthes hamata*. T3 = cut and carry of Ruzi grass (98%) with 2% of weeds. T4 = rotational grazing in Ruzi grass pasture + concentrate. T5 = cut and carry of Ruzi grass (98%) with 2% of weeds + concentrate. Y_m = methane emission rate (enteric methane energy per gross energy intake, %).

Discussion

1. Animal performance, nutrient intake and digestibility

Ruzi grass (*Brachiaria ruziziensis*) and concentrate chemical composition (particularly CP and ME) for feed formulation aimed for a rate of 0.5 kg ADG for 200 kg live weight of Thai native beef cattle by the recommendation of WTSR (2010). However, ADG did not reach an expected value. This could be because dry matter yields of forage grasses decreased in September and October 2014 in the late rainy season when amounts of rainfall were 184.6 and 45.1 mm, respectively (UTMS, 2015; Thip-uten, 2019). Forage dry matter yields depend on both rainfall and soil moisture content (Whiteman, 1980).

In addition, it could be attributed to the different herbage composition in natural grassland (T1): 70% *Eragrostis diplachnoides* (Steud.) Stapf, 5% *Imperata cylindrica,* 5% *Brachiaria Ruziziensis*, 5% *Cynodon plectostachyus*, 5% *Panicum maximum* cv. TD58 + *Panicum maximum* cv. Common, 2% *Stylonsanthes hamat*a, 8% forbs, shrubs, and weeds. Chemical composition in T1 showed significantly higher NDF, ADF and ADL contents than other treatments. This led to low DM, CP and ME intake. Therefore, ADG of T1 was negative (-0.054 kg/d). High lignin content in feed acts as a “protector” to microbe digestion in the rumen. The higher the lignin content the lower the digestibility (Van Soest, 1994; McDonald *et al*., 2002).

Our findings agree with DeRamus *et al*. (2003) who found a negative live weight change in grazing beef cattle. Grazing with high level of concentrate supplementation can increase live weight in dairy cattle (Muñoz *et al*., 2015). However, different levels of concentrate fed to grazing dairy cattle did not alleviate negative live weight (Jiao *et al*., 2014). This could be attributable to the energy used in the activity of grazing (Ørskov and Ryle, 1998). Chaokaur *et al*. (2015) also found that the higher the ME content the higher the ADG in Brahman beef cattle.

Nutrient intake (OMI, CPI NDFI and ADFI) and energy intake (GEI, DEI, and MEI) in T1, T2, and T3 were significantly lower ($P<0.01$) than in supplemented treatments although OMI, NDFI and ADFI in T4 did not show significant difference cf. T3. This could be due to T4 and T5 were received concentrate supplementation where higher CPI and energy intake. On the other hand, the lower nutrient digestibility in T5 than T4, T3, T2, and T1 could be because the high rate of passage of diet in T5 through rumen made a decrease in time of fermentation where the highest fecal excretion was found in T5. Moreover, the higher nitrogen excretion in T4 and T5 can explain the excess of nitrogen in concentrate for animal growth while CP in non-supplemented treatments does not meet the need of the requirement. The lowest of appearance nutrient digestibility in T5 could be possible that the higher intake of concentrate in T5 (1.24 kg DM/day) than T4 (1.01 kg DM/day) where the high total DMI and crude fat (EE) in T5 was higher than T4. This led to the slow digestibility of fibrolytic bacteria to fat coated feed particles (McDonald *et al*., 2002; Hristov *et al*., 2013).

2. Methane emission

Although, statistical analysis showed non significant difference among treatments of methane emission values. When considered numeric term of methane productions, T5 produced lower than the other feeding systems although L/day, g/day, and MJ/day presented higher than T2 and T1. This indicated that high DMI and energy intake in an appropriate feeding system were important factors to mitigate methane emission from animals as reported by many workers (Johnson and Johnson, 1995; DeRamus *et al*., 2003; Knapp *et al*., 2014; Jiao *et al*., 2014; Chaokaur *et al*., 2015). These results could be explained that total methane production (L, g or MJ/day) increases with an increase in DMI because there is more feed to be fermented, whereas methane output is a proportion of CH_4/DMI (L/kg DMI) or CH_4/GEI (MJ/100MJ GEI or %Y_m) and increase of DMI or GEI leads to a decrease of methane (Knapp *et al*., 2014).

Thus, the energy lost in enteric rumen fermented via eructation of methane was expressed as a percentage of GEI or %Y_m value. The group of Thai native beef cattle assigned to confinement systems with cut and carry of Ruzi grass (79%) plus concentrate supplementation (21%) (T5) released methane of 3.05 %Y_m. With the concentrate supplementation of 90% plus 10% by-product of low quality crop residues gave 3.0±1.0 %Y_m (IPCC, 2006). Cut and carry system (T3) of the present work released methane of 4.54 %Y_m whereas 9.9 %Y_m in the high quality sward fed to Charolais cross heifers was reported by Hart *et al*. (2009). Continuous grazing in natural pasture (T1) of the present work released methane of 7.46 %Y_m and was lower than McCaughey *et al*. (1999) and Hart *et al*. (2009). This could be lower DMI of Thai native beef cattle of the present work cf. the higher DMI of Charolais cross and Hereford-Simmental heifers. T2 in rotational grazing in Ruzi grass with no concentrate supplementation of the present work gave 3.37 %Y_m and was lower than 6.38 %Y_m as reported by van Wyngaard *et al*. (2018) in Jersey cows. T4 in rotational grazing with concentrate supplementation (20%) of the present work gave 5.12 %Y_m and was lower than 6.12 %Y_m in forage to concentrate ratio of 76:24 fed to Jersey cows as reported by Van Wyngaard *et al*. (2018). Muñoz *et al*. (2015) reported that 6.4 %Y_m in forage to concentrate ratio of 95:5 fed to Holstein Friesian dairy cows.

These results can explain with the complex pattern of interactions of level of methane emissions with the influence of energy intake, animal and diet factors viz. quantity and quality of feed, animal body weight, age, and amount of exercise. Therefore, assessment methane emission from enteric fermentation in any particular county requires a detail description of species, age, and productivity categories of livestock combines with information of the daily feed intake and the feed's methane conversion rate (Steinfeld and Wassenaar, 2007). This indicates that the low methane emission of the Thai native beef cattle species can reduce methane production with appropriate feeding system.

Conclusion

To mitigate methane emission in Thai native beef cattle, the feeding system to receive a good performance should be cut and carry with 1% body weight of concentrate supplementation.

Acknowledgements

The authors gratefully acknowledge the National Research Council of Thailand for budget support, Udon Thani Animal Nutrition Development Station, Department of Livestock Development (DLD) for animals and experimental site and Japan International Research Center for Agricultural Sciences (JIRCAS) for their kind support in methane measurement equipment.

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