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

Suwit Thip-uten¹, Suradej Pholsen^{1*}, Kritapon Sommart¹, Thumrongsakd Phonbumrung², Yinmin Cai³ and D.E.B Higgs⁴

¹Department of Animal Science, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand

²Bureau of Animal Nutrition Development, Department of Livestock Development, Bangkok 10400, Thailand

³Japan International Research Center for Agricultural Sciences (JIRCAS), Ohwashi, Tsukuba, Ibaraki 305-8686, Japan

⁴Department of Biological and Environmental Sciences, University of Hertfordshire, Hatfield, Hertfordshire, UK. AL10 9AB

Abstract

Despite of concentrate supplements in ruminant diets have been recognized as an influence enteric methane abatement 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 (IPCC, 2006). 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

*ผู้เขียนให้ติดต่อ: E-mail: surpho@kku.ac.th

สมรรถนะการเจริญเติบโตและการผลิตแก๊สมีเทนของโคเนื้อพื้นเมืองไทยที่ปล่อยแพะเล็มและการตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมและไม่เสริมอาหารชั้น

สุวิทย์ ทิพอุเทน¹, สุรเดช พลเสน^{1*}, กฤตพล สมมาตย์¹, อารังศักดิ์ พลบำรุง², Yinmin Cai³
และ D.E.B Higgs⁴

¹ภาควิชาสัตวศาสตร์ คณะเกษตรศาสตร์ มหาวิทยาลัยขอนแก่น อำเภอเมือง จังหวัดขอนแก่น 40002

²สำนักพัฒนาอาหารสัตว์ กรมปศุสัตว์ กรุงเทพมหานคร 10400

³Japan International Research Center for Agricultural Sciences (JIRCAS), Ohwashi, Tsukuba, Ibaraki 305-8686, Japan

⁴Department of Biological and Environmental Sciences, University of Hertfordshire, Hatfield, Hertfordshire, UK. AL10 9AB

บทคัดย่อ

ถึงแม้การเสริมอาหารชั้นในอาหารสัตว์เคี้ยวเอื้องทราบดีว่าเป็นอีกกลยุทธ์ที่สามารถช่วยลดการผลิตแก๊สมีเทนจากกระบวนการหมักในกระเพาะรูเมนได้ แต่การวิจัยเกี่ยวกับผลของการเสริมอาหารชั้นต่อการผลิตแก๊สมีเทนจากกระบวนการหมักในกระเพาะรูเมนของสัตว์เคี้ยวเอื้องภายใต้สภาพปล่อยแพะเล็มในทุ่งหญ้าของประเทศไทยยังมีน้อย ดังนั้นการศึกษานี้จึงมีวัตถุประสงค์เพื่อประเมินสมรรถนะการเจริญเติบโตและการปลดปล่อยแก๊สมีเทนจากโคเนื้อพื้นเมืองไทย ภายใต้ระบบการปล่อยแพะเล็มในแปลงพืชอาหารสัตว์และระบบการตัดไปให้กินที่คอกร่วมกับการเสริมและไม่เสริมอาหารชั้น ใช้โคเนื้อพื้นเมืองไทยสามสิบตัวเป็นเพศผู้ตอนและเพศเมียอย่างละสิบห้าตัว สุ่มให้ได้รับระบบการเลี้ยงที่ต่างกันคือ T1 = ปล่อยแพะเล็มในแปลงหญ้าธรรมชาติแบบต่อเนื่อง, T2 = ปล่อยแพะเล็มในแปลงหญ้ารูซี่แบบหมุนเวียน, T3 = ตัดหญ้ารูซี่ไปให้กินที่คอก, T4 = ปล่อยแพะเล็มในแปลงหญ้ารูซี่ร่วมกับการเสริมอาหารชั้นให้กินหนึ่งเปอร์เซ็นต์ของน้ำหนักตัวต่อวัน และ T5 = ตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมอาหารชั้นให้กินหนึ่งเปอร์เซ็นต์ของน้ำหนักตัวต่อวัน ตามลำดับ ในแผนการทดลองแบบสุ่มสมบูรณ์ภายในบล็อกใช้โคหกตัวต่อระบบการเลี้ยง พบว่าน้ำหนักตัวของโคในระบบการเลี้ยงแบบปล่อยแพะเล็มในทุ่งหญ้าธรรมชาติอย่างต่อเนื่อง (T1) โคในระบบการปล่อยแพะเล็มแบบหมุนเวียน (T2) และโคในระบบการตัดหญ้ารูซี่ไปให้กินที่คอกไม่เสริมอาหารชั้น (T3) ทำให้โคมีน้ำหนักตัวลดลง การปล่อยโคพื้นเมืองไทยเข้าแพะเล็มแบบต่อเนื่องในทุ่งหญ้าธรรมชาติโดยไม่เสริมอาหารชั้น (T1) ให้ค่าอัตราการปลดปล่อยแก๊สมีเทนจากพลังงานรวมที่กินได้ทั้งหมด 7.46 %Y_m ซึ่งอยู่ในช่วง 6.5±1.0 %Y_m ตามข้อเสนอของคณะกรรมการระหว่างรัฐบาลว่าด้วยการเปลี่ยนแปลงสภาพภูมิอากาศ (IPCC, 2006) ขณะที่โคพื้นเมืองไทยที่ใช้ระบบการเลี้ยงแบบตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมอาหารชั้น (T5) ให้ค่าอัตราการปลดปล่อยแก๊สมีเทนจากพลังงานรวมที่กินได้ทั้งหมด 3.05 %Y_m จากการศึกษาเสนอแนะว่าการเลี้ยงโคในระบบการตัดหญ้ารูซี่ไปให้กินที่คอกร่วมกับการเสริมอาหารชั้น 1 เปอร์เซ็นต์ของน้ำหนักตัว สามารถลดปริมาณการปลดปล่อยแก๊สมีเทนและทำให้สมรรถนะการเจริญเติบโตของโคเพิ่มขึ้น

คำสำคัญ: ระบบการให้อาหาร แพะเล็ม ตัดไปให้กิน มีเทน และ โคเนื้อพื้นเมืองไทย

*Corresponding author: E-mail: surpho@kku.ac.th

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 CH₄ from beef and dairy cattle annually. CH₄ 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 CH₄ production from confined Thai native cattle on forage based diets (Chaokaur *et al.*, 2015; Chuntrakort *et al.*, 2014; Phromlounsri *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 \pm 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. SF₆ 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 N₂ flow rate at 30 mL/min. Standard gas was 0.1 and 0.5 ppb of SF₆ with N₂ balance. CH₄ 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 N₂. Standard gas was 200 ppm of CH₄ with N₂ 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 ANKOM²⁰⁰ 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 $100 \times \text{kg of external indicator (Cr}_2\text{O}_3\text{) fed} \div \text{percentage of external indicator in feces}$.

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 $100 - [100 \times (\text{marker in diet} \div \text{marker in feces})]$ according to Schneider and Flatt (1975) and Coleman (2005).

Digestion coefficient of a nutrient (OM, CP, NDF and ADF) was calculated by using formula: $100 - (100 \times \% \text{ AIA in feed} \times \% \text{ nutrient in feces}) \div (\% \text{ AIA in feces} \times \% \text{ nutrient in feed})$ (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): $\text{DE} = [\text{energy intake (kJ)} - \text{energy in feces (kJ)}] \div \text{DMI (kg)}$. ME content (MJ/kg DM) of feed was calculated according to WTSR (2010) equation as $\text{ME} = (\text{DE} \times 0.9613) - 1.2276$.

Daily enteric CH₄ emission from each animal was calculated according to Johnson *et al.* (1994), using the known permeation rate of SF₆

and the concentrations of SF₆ background and CH₄ in the breath samples using formula: CH₄ (g/d) = SF₆ permeation rate (g/d) × (CH₄ ÷ SF₆). CH₄ 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 CH₄ 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 CH₄ per GE intake were not significantly different (P>0.05) among treatments.

Our results showed that Thai native beef cattle released CH₄ 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.

CH₄ 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 $P \leq 0.05$ 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 (Thiputen 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 $P \leq 0.05$. ns = non significance, * $P \leq 0.05$, ** $P \leq 0.01$. 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 hamata*, 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 CH₄/DMI (L/kg DMI) or CH₄/GEI (MJ/100MJ GEI or %Y_m) and increase of DMI or GEI leads to a decrease of methane as reported by 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.

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References

- Agricultural Research Council (ARC). 1980. The Nutrient Requirement of Ruminant livestock. CAB International, Wallingford, UK.
- Association of Official Analytical Chemists (AOAC). 1990. Official Methods of Analysis (15thed). Washington, DC: Author.
- Chaokaur, A. 2011. Current status of methane emission from cattle in Thailand. The 3rd International Conference on Sustainable Animal Agriculture for Developing Countries (SAADC2011). July 26-29, 2011 Nakhon Ratchasima, THAILAND.
- Chaokaur, A., Nishida, T., Phaowphaisal, I. and Sommart, K. 2015. Effects of feeding level on methane emissions and energy utilization of Brahman cattle in the tropics. *Agriculture, Ecosystems and Environment*. 199: 225–230.
- Chuntrakort, P., Otsuka, M., Hayashi, K., Takenaka A., Udchachon, S., and Sommart, K. 2014. The effect of dietary coconut kernels, whole cottonseeds and sunflower seeds on the intake, digestibility and enteric methane emissions of Zebu beef cattle fed rice straw based diets. *Livestock Science*. 161 : 80–89.
- Coleman, S. W. 2005. Predicting forage intake by grazing ruminants. *Proc. 16th Florida Ruminant Nutrition Symposium*. 352 : 72–90.
- DeRamus, H. A., Clement, T. C., Giampola, D. D., and Dickison, P. C. 2003. Methane emissions of beef cattle on forages: Efficiency of grazing management systems. *Journal Environmental Quality*. 32: 269-277.
- Eckard, R. J., Grainger, C., and de Klein, C. A. M. 2010. Options for the abatement of methane and nitrous oxide from ruminant production: A review. *Livestock Science* 130: 47-56.

- Grainger, C., and Beauchemin, K.A. 2011. Can enteric methane emissions from ruminants be lowered without lowering their production?. *Animal Feed Science and Technology* 166– 167: 308–320.
- Hart, K. J., Martin, P. G., Foley, P. A., Kenny, D. A., and Boland, T. M. 2009. Effect of sward dry matter digestibility on methane production, ruminal fermentation, and microbial populations of zero-grazed beef cattle. *Journal of Animal Science* 87: 3342-3350.
- Hristov, A. N., Oh, J., Firkins, J. L., Dijkstra, J., Kebreab, E., Waghorn, G., Makkar, H. P. S., Adesogan, A. T., Yang, W., Lee, C., Gerber, P. J., Henderson, B., and Tricarico, J. M. 2013. Special Topics- Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane mitigation options. *Journal of Animal Science*. 91 : 5045-5069.
- Intergovernmental Panel on Climate Change (IPCC). 2006. Emissions from livestock and manure management. *Guidelines for National Greenhouse Inventories, vol.4. Agriculture, Forestry and Other Land Use* 10. 1–10.87 (Chapter 6 and 10).
- Jiao, H.P., Dale, A.J., Carson, A.F., Murray, S., Gordon, A.W., and Ferris, C.P. 2014. Effect of concentrate feed level on methane emissions from grazing dairy cows. *Journal of Dairy Science*. 97 : 7043–7053.
- Johnson, K. A., Huyler, M., Westberg, H., Lamb, B., and Zimmerman, P. 1994. Measurement of methane emissions from ruminant livestock using a SF6 tracer technique. *Environmental Science & Technol.* 28: 359–362.
- Johnson, K. A., and Johnson, D. E. 1995. Methane emission from cattle. *Journal of Animal Science*. 73: 2483-2492.
- Knapp, J. R., Laur, G. L., Vadas, P. A., Weiss, W. P., and Tricarico, J. M. 2014. Enteric methane in dairy cattle production: Quantifying the opportunities and impact of reducing emissions. *Journal of Dairy Science*. 97: 3231-3261.
- Kurihara, M., Magner, T., Hunter, R.A., and McCrabb, G.J. 1999. Methane production and energy partition of cattle in the tropics. *British Journal of Nutrition*. 81: 227-234.
- McCaughy, W. P., Wittenberg, K., and Corrigan, D. 1999. Impact of pasture type on methane production by lactating beef cows. *Canada Journal of Animal Science* [online]. [Accessed September 18, 2016] Available from: URL :<http://www.nrcresearchpress.com/doi/10.4141/A98-107#.XHXM3rgxXIU>.
- McDonald, P., Edward, R. A., Greenhalgh, J. F. D., and Morgan C. A. 2002. *Animal Nutrition*. 6th Longman Scientific and Technical. New York.
- Muñoz, C., Hube, S., Morales, M. J., Yan, T., and Ungerfeld, E. M. 2015. Effects of concentrate supplementation on enteric methane emissions and milk production of grazing dairy cows. *Livestock Science*. 175:37-46.

- O'Mara, F. P. 2011. The significance of livestock as a contributor to global greenhouse gas emissions today and in the near future. *Journal of Animal Feed Science and Technology*. 166-167:7-15.
- Ørskov, E. R., & Ryle, M. 1998. *Energy Nutrition in Ruminants*. Chalcombe Publications, Painshall, Church Lane, Welton, Lincoln, LN2 3LT, United Kingdom.
- Phromlounsri, A., Hayashi, K., Otsuka, M., Udchachon, S., and Sommart, K. 2012. Effects of energy intake level on methane production of Thai Native and Brahman crossbred cattle. *Khon Kaen Agriculture Journal*. 40(Supplement), S5–S11. (in Thai)
- SAS. 1996. *User's Guide: Statistic, Version 6, 12th ed.* SAS Inst. Inc., Cary, NC.
- Schneider, B. H., and Flatt, W. P. 1975. *The evaluation of feeds through digestibility experiments*. The University of Georgia Press, Athens, Georgia, U. S. A.
- Steel, R. G. D., and Torrie, J. H. 1980. *Principles and Procedure of Statistics*. McGraw-Hill Book Co. Inc., New York, NY.
- Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., and de Hann, C. 2006. *Livestock's long shadow – Environmental issues and options*. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Steinfeld, H., Gerber and Wassenaar, P. 2007. The role of livestock production in carbon and nitrogen cycles. *Annu. Rev. Environ. Resour.* 32:271-94.
- Suzuki, T. 2015. Methods to determine the methane production from cattle in KKU and CTU: Document's Workshop on "Progress and goals for the JIRCAS collaborative project; Establishment of monitoring technology and development of mitigation technologies of methane emission from enteric fermentation; February, 2015 at Hotel Pullman Raja Orchid, Khon Kaen.
- Thip-uten, S., and Sommart, K. 2012. Prediction Equations of Metabolizable Energy content in Beef Cattle Diets. 17(1): 35-44. [online]. [Accessed September 18, 2016] Available from: URL: http://resjournal.kku.ac.th/scitech/abs/a17_01_35.asp?vol=17 (in Thai)
- Thip-uten, S. 2019. Greenhouse gases emission, carbon footprint of Thai native beef cattle, and soil carbon sequestration in pasture under different raising systems during raining season. A thesis submitted in partial fulfillment of the requirements for the degree of doctor of philosophy in animal science. Graduate school Khon Kaen University. (in Thai)
- UTMS (Udon Thani Meteorological Station). 2015. Monthly amount of rainfall (mm) of nine-year period and the year 2014. (Private contact).
- Van Keulen J., and B. A. Young. 1977. Evaluation of acid insoluble ash as a natural marker in ruminant digestibility studies. *Journal of Animal Science*. 44: 282.

Van Soest, P.J., Robertson, J.B., and Lewis, B.A. 1991. Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition. *Journal of Dairy Science*. 74, 3583–3597.

Van Soest, P.J. 1994. *Nutritional ecology of the ruminant*. Second edition. Cornell University.

Van Wyngaard, J. D. V., Meeske, R., and Erasmus, L. J. 2018. Effect of concentrate feeding level on methane emissions, production performance and rumen fermentation of Jersey cows grazing ryegrass pasture during spring. *Animal Feed Science and Technology*. 241:121-132.

Whiteman, P. C. 1980. *Tropical pasture science*. Oxford University Press, New York.

WTSR (The Working Committee of Thai Feeding Standard for Ruminant). 2010. *Nutrient Requirement of Beef Cattle in Indochinese Peninsula*. Klunghanavitthaya Press, Khon Kaen, Thailand.