CHAPTER IV

EXPERIMENT 2: METABOLIZABLE ENERGY REQUIREMENT OF GROWING THAI NATIVE CATTLE BY USING INDIRECT ANIMAL CALORIMETRY

4.1 Introduction

The NRC guidelines for beef cattle production (NRC, 2000) are commonly used to formulate diets and evaluate feeding programs around the world (Chizzotti et al., 2008; Tedeschi et al., 2002). In tropical feeding recommendation, Kearl (1982) suggested that the metabolizable energy requirement for maintenance of beef cattle was 493 KJ/kgBW$^{0.75}$/d, but recommendation for beef cattle in temperate zone by NRC (1976) reported that 540 KJ/kgBW$^{0.75}$/d. In Thailand, Thai native breed was representing more 70% of the country's beef cattle herd (DLD, 2008). They have been raised under more extensive conditions and considered to be well adapted to heat stress, disease and low quality feeds of humid tropical zone. Nutritional feeding guidelines of native beef cattle have not been well defined because paucity of information on nutrient requirement. In previous study, Nitipot et al. (2009) analyzed data by using meta-analysis and suggested that metabolizable energy for maintenance of Thai native beef cattle was 484 KJ/kgBW$^{0.75}$/d. However, the work of Nitipot et al. (2009) and Kawashima et al. (2000) also does not support other breed of tropical zone, such as Brahman cattle in Thailand from report of Chaokaur et al. (2007) and Kedah Kelantan in Malaysian from report of Laing and Young (1995). However, nutrients recommended of Thailand were developed from small database, therefore, this study was aimed to determine energy requirements for maintenance of Thai native beef cattle.

4.2 Materials and Methods

4.2.1 Animals and experimental design

Fifteen bull Thai native beef cattle, with an average body weight of 268±26 kg and 23 months of age were housed individually stall with free access to drinking water and mineral block. This study was carried out from December 2008 to January 2009 at Khon Kaen animal nutrition research center, Thapra, Khon Kaen, Thailand. All animals were treated to remove endo and ecto parasites prior to start of the experiment, the animals were halter-trained and adapted to handling and to the respiration chambers for 1 month before the trial started. In adaptation period, they were fed at 1.5 of maintenance. In experimental period, five animals were randomly allocated to one of three dietary treatments in a completely randomized design. Treatments were the level of metabolizable energy intake (MEI) according to WTSR (2008) recommendation of metabolizable energy for maintenance requirement (M= 484 kJ/kgBW$^{0.75}$/d) as follows; T1 = 1.1 of maintenance (1.1M), T2 = 1.5 of maintenance (1.5M) and T3 = 1.9 of maintenance (1.9M).

4.2.2 Feed preparation and management

The experimental diet consisted of 32% Guinea hay, 32% cassava chip, 18% ricebran, 7% soybean meal, 6% palm meal, 4% coconut meal, 0.5% urea and 0.5% mineral (Dry matter basis)(Table 4.1). Animal were fed twice daily at 09.00 and 16.00 h. They were allowed for adaptation period of 30 days prior to 116 days of data collection period. During metabolic trial period, animals were moved to respiration chamber with head hood. Animals were weighed on the first day, the body weight of each animal were used to calculate feeding level.

Table 4.1 Ingredients and chemical composition of feed in experiment

Item	DM basis (%)
Ingredients	
Guinea grass hay	32
Cassava chip	32
Rice bran	18
Soybean meal	7
Coconut meal	4
Palm kernel cake	6
Urea	0.5
Mineral mixed	0.5
Chemical composition , %	
DM	90.93
CP	10.61
Ash	7.31
OM	92.69
EE	3.49
NDF	36.33
ADF	21.72
Energy content, MJ/kg DM	
GE	17.69
DE	13.12
ME	10.29

4.2.3 Data collection and chemical analysis

4.2.3.1 Digestion trial

Feed offer, feed refusal, feces and urine samples of each animal were weighed, individually homogenized. Sample of feed refusal, feces (1 kg) and urine (500 ml) were sampling daily in the morning for 7 days and stored at -18 °c. At the end of each period, all samples were thawed, mixed thoroughly, sub-sample (2.5 kg of feces and 500 ml of urine) and oven-dried (refusal and feces) at 60 °c for at least 72 h. Refusal and feces were ground to pass through a 1-mm.screen (Retsch, Model: SM 2000/695 Upm. GmbH&Co.kG Rheinische strabe 36, 42781 Haan. Germany) and stored until analyzed dry matter, crude protein, ether extract and ash according to AOAC (1990). Neutral detergent fiber and acid detergent fiber were analyzed according to Van Soest (1970).

Composite of urine were taken for N determination with Kjeldahl N procedure. Gross energy (GE) was determined in a SHIMADZU auto-calculating bomb calorimeter. Digestible energy (DE) was computed from GE of feeds, orts, and feces. The metabolizable energy intake (MEI) was calculated as the difference between GE intake and energy loss in feces, urine and methane production.

4.2.3.2 Gas exchange measurement

The oxygen consumption, carbon dioxide and methane production of each animal were measured with the ventilated flow-through method using head hood chamber (head box, open-circuit, indirect respiration calorimetry system) for 3 days of collection period. The system consisted of a head hood and flow meter using a thermal flow cell (NIPPON FLOW CELL Co., Ltd., Japan, model FWH-N-S) which was used to record flow rate and total volume of air flowing out from the respiration chamber. The samples of outflow and incoming air collected were analyzed for oxygen using a dual chamber paramagnetic oxygen analyzer (Servomex Pcl., UK, model Xentra 4100), for carbon dioxide and methan using an infrared gas analyzer (HORIBA, Japan, model VIA 510). The temperature and humidity of out flowing air was thermo recorded electronically (ESPEC MIC CORP, Japan, model RS-12).The gas analyzers were calibrated against certified gases (TAKACHIHO CHEMICAL INDUSTRIAL Co., Ltd, Japan), with known gas concentrations once a day (These measurements were conducted 23.30 hours per day, from 09.30 of started day to 09.00 of next measured day). Data recording program used software of TESTPOINT. The system also allowed measurement of the concentration of ambient oxygen. The calorimetry system was calibrated by the CO_2 injection method (by releasing a weighed amount of CO_2 gas into the system). The details of the method were determined according to the procedure of Suzuki et al. (2008).

Heat production was calculated from oxygen consumption, carbon dioxide and methane production with correction for urinary N loss by the equation according to Brouwer (1965) as followed;

$$HP (KJ/d) = 16.18*O_2 + 5.02*CO_2 - 2.17*CH_4 - 5.99*N$$

where O_2 represent to volume of oxygen consumed (litres), CO_2 represent to carbon dioxide production (litres), CH_4 represent to methane production (litres) and N represent to urinary nitrogen excretion (g).

4.2.4 Calculations and statistical methods

All data were analyzed by using general linear models procedure and treatment means were compared by Duncan news's multiple range test (SAS, 1996) according to a completely randomized design as following model;

$$Y_{ij} = \mu + T_i + \varepsilon_{ij}$$

Where Y_{ij} = observed data,; μ = overall mean; T_i = effect of dietary treatment,; and ε_{ij} = error.

Polynomial contrasts were used to determine the influence of increasing energy intake on animal performance using PROC GLM of SAS with a $P<0.05$ significant level.

Requirements for maintenance and growth were estimated by using the Proc REG procedure of SAS according to Luo et al. (2004) and McDonald et al. (2005). All data were constructed and analyzed to determined requirement for maintenance by regressing energy retention (KJ/kgBW$^{0.75}$/d) against metabolizable energy intake (KJ/kgBW$^{0.75}$/d) as followed;

$$ER = a + b \text{ MEI}$$

From the obtain equations, metabolizable energy requirement for maintenance was determined by using calculated by assuming that maintenance requirement are value at which energy retention is equal to zero (Y-intercept; *a*) and the slope (*b*) was the efficiencies of metabolizable energy utilization for maintenance according to the method suggested by McDonald et al. (2002) and Luo et al. (2004).

4.3 Results and Discussion

4.3.1 Feed intake and digestibility

Feed intake and digestibility of nutrients were shown in Table 4.2. Dry matter intake, where expressed in kg dry matter per day was increased with increasing level of ME intake ($P<0.05$). Feed intake on basis of percent of body weight and metabolic body weight for cattle fed 1.5M and 1.9M were higher ($P<0.05$) than that cattle fed 1.1M, but no differences were observed among 2 treatments (1.5M and 1.9M). All nutrients intake were increased ($P<0.05$) with increasing energy intake, but there was no significant difference among 1.5M and 1.9M in ether extract (EE) intake, neutral detergent fiber (NDF) intake and acid detergent fiber (ADF) intake. Actual ME intake were 1.17 M by 1.1M, 1.55 M by 1.5 M and 1.68 M by 1.9 M, respectively. These results, indicated that ME intake of cattle in 1.5M was similar to cattle in 1.9M, and 1.68 M could be represented as *ad libitum* level. Apparent digestibility of all nutrients except for NDF were not significantly ($P>0.05$) affected by the difference of ME intake. NDF digestibility of cattle fed 1.1M was highest and decreased with increasing level of ME intake. These results indicated that the ability to digest fiber or the NDF digestibility of Thai native can not be improved by increasing energy intake. This is in contrast to the suggestion of Bartlett et al. (2006) and Sauvant and Giger-Reverdin (2007), who found that as increased feeding level can improved diet digestibility in ruminants. However, the results from this study were similar to Chaokaur et al. (2008) for Brahman cattle and Chantiratikul and Chumpawadee (2008) for the Thai native heifer, who reported an increased feeding energy level with decreased NDF digestibility. These current findings indicated that an increased feeding level cannot improve nutrients digestibility. Similarly, Hindrichsen et al. (2003) and Pittroff et al. (2006), who reported that increased forage intake resulted in decreased digestion of organic matter (OM) and NDF. Moreover, this study was in good agreement with the report of O'Mara et al. (1999) and Woods et al. (1999), who found that NDF digestibility decreased when energy intake was increased from maintenance to 2 x of maintenance.

Table 4.2 Nutrients intake and digestibility of Thai native cattle fed various energy levels

Item	Levels of energy feeding			SEM	Polynomial contrast	
	1.1M	1.5M	1.9M		*L*	*Q*
Number animal, head	*n = 5*	*n = 5*	*n = 5*			
Body weight, kg	260.50^{b}	285.13^{ab}	312.13^{a}	10.83	0.01	0.93
initial weight, kg	259.75	283.75	312.25	11.3	*<0.01*	*<0.01*
final weight, kg	261.25	286.50	312.00	10.41	*<0.01*	0.99
Metabolic body weight, kg	64.76^{b}	69.38^{ab}	74.26^{a}	2.02	*<0.01*	0.96
Feed intake						
kgDM/d	3.39^{c}	4.91^{b}	5.48^{a}	0.14	*<0.01*	0.03
%BW	1.31^{b}	1.72^{a}	1.75^{a}	0.02	*<0.01*	*<0.01*
g/kgBW$^{0.75}$/d	52.32^{b}	70.70^{a}	73.71^{a}	0.99	*<0.01*	*<0.01*
Nutrients intake, kg/d						
OM	3.14^{c}	4.55^{b}	5.10^{a}	0.14	*<0.01*	0.03
CP	0.36^{c}	0.52^{b}	0.61^{a}	0.02	*<0.01*	0.29
EE	0.12^{b}	0.17^{a}	0.19^{a}	0.01	*<0.01*	0.28
NDF	1.23^{b}	1.78^{a}	1.72^{a}	0.11	*<0.05*	0.06
ADF	0.73^{b}	1.06^{a}	1.02^{a}	0.07	*<0.05*	0.07
Nutrients digestibility, %						
DM	71.48	69.79	71.57	0.88	0.94	0.14
OM	76.04	73.37	75.07	0.89	0.47	0.10
CP	66.13	63.20	67.05	1.78	0.72	0.15
NDF	52.24^{a}	49.59^{ab}	44.11^{b}	2.04	0.02	0.58
ADF	45.19	43.59	38.39	3.64	0.21	0.69
EE	87.31	80.00	86.18	3.65	0.84	0.18

$^{a-c}$ Within a row, means without a common superscript letter differ *(P<0.05)*

4.3.2 Energy metabolism

Energy metabolism and energy loss are shown in Table 4.3. Energy excretion in feces and heat production were lower in 1.1M than that 1.5M and 1.9M, but there was no difference (*P*>0.05)in these values between the 1.5M and the 1.9M groups. Energy loss in urine and urine volume were not different (*P*>0.05) in all treatments. Heat production loss in MJ per day and heat production loss per GEI were not difference among 1.5M and 1.9M (*P*>0.05), but higher (*P*<0.05) than that of cattle fed 1.1 M.

Methane production, where expressed in liter per day and MJ per day, was lowest in 1.1M and highest in 1.9M, but the proportion of methane energy loss per GEI and heat energy loss per GEI were decreased with an increasing level of MEI.

Methane energy loss per kg of organic matter intake (OMI) was lowest in 1.9M and highest in 1.1M. Methane energy loss per GEI from this study ranges from 8.40%-9.97%, which was close to the figure reported by Johnson and Johnson (1995), who found that energy loss as methane from cattle range from 2-12% of GE intake, but higher than the report of Johnson and Ward (1996), who found that methane production by cattle typically accounts for 5.5-6.5% of GEI. Moreover, this result was similar to that reported by Yan et al.(2002) and Chaokaur et al. (2008) who found that an increased feeding level can be reduce energy loss in methane as proportion of GEI and similar to the report of Krishna et al. (1978) which estimated higher methane yields of 9% in Indian cattle fed above maintenance diet. This work supports the report of Chaokaur et al. (2008), who found that methane energy per GEI was decreased from 11.51% to 7.98%, when increasing the MEI from maintenance level to *ad libitum*. Moreover, the result from this study supports the work of Gabel et al. (2003), who found that methane energy loss decreased with increased nutrient intake of cows. This finding indicated that an increasing energy intake can reduce methane loss per OMI and methane loss per GEI.

4.3.3 Energy partition

Energy partition was compared among treatments on the basis of metabolic body weight as shown in Table 4.3. GE intake and DE intakes were influenced ($P<0.05$) by levels of ME intakes. Energy loss in feces, methane production and heat production were lowest in 1.1 M and highest in 1.9M group, but there was no difference ($P>0.05$) between 1.5M and 1.9M group. This study was in good agreement with Clark et al. (2007), who found that fecal and gaseous energy losses were similar between steer fed *ad libitum* and 90% of *ad libitum*, but was higher ($P<0.05$) than cattle fed 80% of *ad libitum*.

Table 4.2 Energy metabolism of Thai native cattle fed various energy levels

Item	Levels of energy feeding			SEM	Polynomial contrast	
	1.1M	1.5M	1.9M		*L*	*Q*
Number of animal, head	*n = 5*	*n = 5*	*n = 5*			
Body weight, kg	260.50[b]	285.13[ab]	312.13[a]	10.83	0.01	0.93
Metabolic body weight, kg	64.76[b]	69.38[ab]	74.26[a]	2.02	*<0.01*	0.96
Gross energy intake, MJ/d	59.98[c]	86.85[b]	96.82[a]	2.65	0.01	0.03
Energy partition, KJ/kgBW$^{0.75}$/d						
GE intake	926.08[b]	1251.78[a]	1303.17[a]	17.73	*<0.01*	*<0.01*
DE intake	679.69[c]	884.59[b]	945.03[a]	14.44	*<0.01*	*<0.01*
ME intake	568.11[c]	753.02[b]	812.30[a]	12.56	*<0.01*	*<0.01*
Feces excretion						
Feces, kgDM/d	0.97[b]	1.48[a]	1.56[a]	0.07	*<0.01*	0.03
Feces energy, MJ/d	15.99[b]	25.49[a]	26.62[a]	1.17	*<0.01*	0.02
Feces energy, KJ/ kgBW$^{0.75}$/d	246.38[b]	367.19[a]	358.15[a]	12.02	*<0.01*	*<0.01*
Feces energy/GEI	26.61	29.33	27.45	0.95	0.55	0.08
Urine excretion						
Urine volume, L/d	5.56	6.69	4.36	1.18	0.49	0.26
Urine energy, MJ/d	1.23	1.65	1.7	0.16	0.07	0.37
Urine energy, KJ/ kgBW$^{0.75}$/d	19.21	23.73	22.86	2.32	0.29	0.36
Urine energy/GEI	2.08	1.89	1.74	0.18	0.24	0.96
Methane production						
CH_4 production, L/d	150.80[b]	189.68[ab]	206.64[a]	12.77	0.02	0.50
CH_4 production, L/kgOMI	48.18[a]	41.61[ab]	40.34[b]	2.11	0.03	0.33
CH_4 production,L/kgNDFI	122.92	106.26	121.56	6.28	0.88	0.07
CH_4 energy, MJ/d	5.96[b]	7.49[ab]	8.17[a]	0.51	0.02	0.51
CH_4 energy, KJ/ kgBW$^{0.75}$/d	92.38[b]	107.85[a]	109.87[a]	6.11	0.07	0.39
CH_4 energy/GEI	9.97[a]	8.62[ab]	8.40[b]	0.44	0.03	0.32
Heat production						
Heat energy, MJ/d	35.09[b]	44.99[a]	48.72[a]	1.58	*<0.01*	0.15
Heat energy, KJ/ kgBW$^{0.75}$/d	543.33[b]	647.52[a]	655.98[a]	15.8	*<0.01*	0.04
Heat energy/GEI	58.66[a]	51.72[b]	50.39[b]	1.53	*<0.01*	0.17
Energy retention, KJ/ kgBW$^{0.75}$/d	24.78[b]	105.50[a]	156.32[a]	19.77	*<0.01*	0.55
Energitic efficiency						
DE/GE	0.73	0.71	0.73	0.009	0.60	0.11
ME/GE	0.61	0.6	0.63	0.01	0.33	0.15
ME/DE	0.84	0.85	0.86	0.007	0.05	0.61

[a-c] Within a row, means without a common superscript letter differ *($P<0.05$)*

Energy retention also increased with an increasing level of energy intake, but there was no significant difference (*P*>0.05) between 1.5M and 1.9M group. The ratios of DE to GE, ME to GE and ME to DE were not different (*P*>0.05) in all treatments. However, the ratio of ME to DE from this study (0.84-0.86) was higher than that recommended by NRC (2000) of 0.82. By comparison with other breeds, it is found that the ratio of ME to DE from this study was lower than Brahman cattle fed diet containing energy at 1.4M to *ad libitum* level from report of Chaokaur et al. (2008) (0.86-0.88). The results indicated that an increase in feeding level can improve the energetic efficiency of utilization of ME, when compared to animals fed at above the maintenance level. This finding was similar to the work of Chandramoni et al. (2000) and Olson et al. (2008).

4.3.4 Metabolizable energy requirement for maintenance

All data were constructed and analyzed to determine the requirement for maintenance by regressing energy retention (KJ/kgBW$^{0.75}$/d) against energy intake (KJ/kgBW$^{0.75}$/d). Metabolizable energy for maintenance was estimated by linear regression of energy retention (ER) on metabolizable energy intake (MEI) as shown in figure 4.1.

Metabolizable energy for maintenance of Thai native cattle was determined from this study to be 531.76 KJ/kgBW$^{0.75}$/d, which was similar to the recommendation of ARC (1980) (527 KJ/kgBW$^{0.75}$/d) and NRC (1976) (540 KJ/kgBW$^{0.75}$/d). While, the metabolizable energy for maintenance of Thai native cattle from the recommendation of WTSR (2008) was 484 KJ/kgBW$^{0.75}$/d and reported of Nitipot et al. (2009) was 509 KJ/kgBW$^{0.75}$/d. In comparing this study to other studies, it is found that the metabolizable energy requirement for maintenance from this study was higher than Malaysian Kedah Kelantan from the report of Laing and Young (1995) (335 KJ/kgBW$^{0.75}$/d), Brahman crossbred from the report of Ferrell and Jenkin (1998) (488 KJ/kgBW$^{0.75}$/d) and Nellore cattle from the report of Tedeschi et al. (2002) (498 KJ/kgBW$^{0.75}$/d).

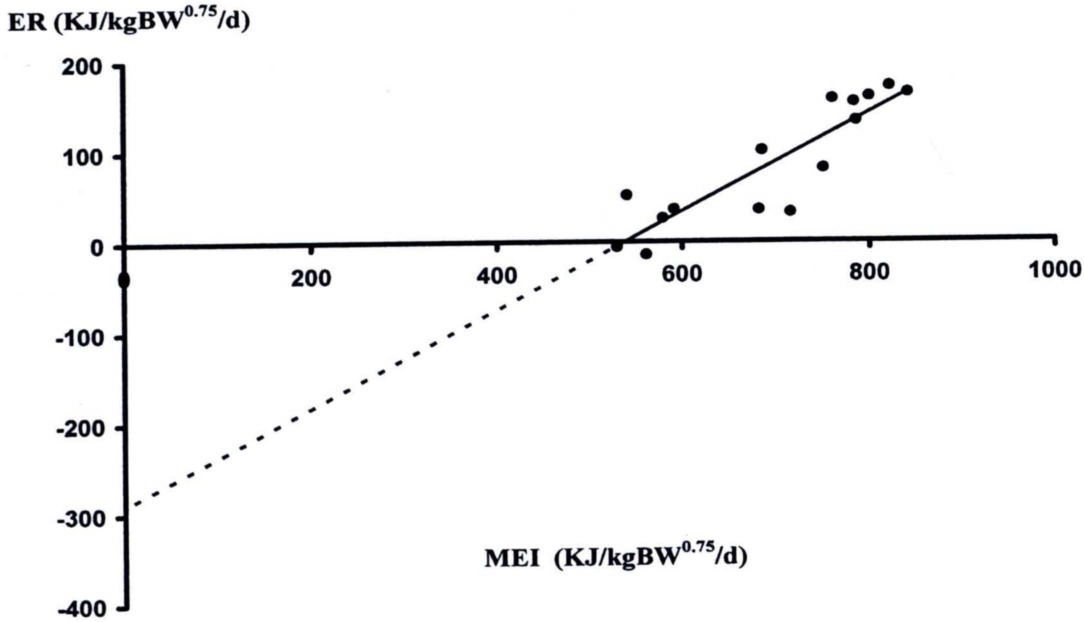

Figure 4.1 Relationship between energy retention (ER, $KJ/kgBW^{0.75}/d$) and metabolizable energy intake (MEI, $KJ/kgBW^{0.75}/d$) describes equation, $ER = (-283.1124)_{(SE=64.4211)} + 0.5324_{(SE=0.0895)}$ MEI ($n=15$, $R^2=0.7793$, $RSD=9.5176$, $P<0.01$)

From this current study, the net energy for maintenance can be estimated by extrapolation to the point of zero metabolizable energy intake; the net energy for maintenance was 283.11 $KJ/kgBW^{0.75}/d$. This study was lower than Tuli cattle from the report of Ferrell and Jenkin (1998) (318.82 $KJ/kgBW^{0.75}/d$) and Nellore cattle from the report of Tedeschi et al. (2002) (323 $KJ/kgBW^{0.75}/d$). This finding indicated that Thai native cattle requires energy for basal metabolism which is lower (about 12.07%) than *Bos taurus* cattle from the recommendation of Lofgreen and Garrett (1968) (322 $KJ/kgBW^{0.75}/d$). This reason could support the hypothesis of NRC (2000), which indicated that the net energy for maintenance of *Bos indicus* was assumed to be 10% lower than *Bos taurus*. However, metabolizable energy and net energy for maintenance estimates vary widely and are not yet clarified, because there are many factors which influence the energy requirement such as biological type, sex, stage and environmental conditions (NRC, 2000; Luo et al., 2004).

4.4 Conclusions

This study provides equations for estimates the metabolizable energy requirement for maintenance of Thai native beef cattle under feeding conditions in Thailand. The results showed that metabolizable energy requirement for maintenance of Thai native cattle was 531.76 $KJ/kgBW^{0.75}/d$. From the equation, can be estimated net energy for maintenance was 283.11 $KJ/kgBW^{0.75}/d$, and efficiency of metabolizable energy for growth was 0.53. However, due to limited data from metabolic trial, the equations recommended were developed from small database. More energy research is needed to better define energy and protein requirement for beef cattle.