CHAPTER III

EXPERIMENT 1: METABOLIZABLE ENERGY REQUIREMENT OF YEARLING THAI NATIVE CATTLE BY COMPARATIVE SLAUGHTER TECHNIQUE

3.1 Part 1: METABOLIZABLE ENERGY REQUIREMENT FOR MAINTENANCE AND GROWTH OF YEARLING THAI NATIVE CATTLE BY USING FEEDING TRIAL METHOD

3.1.1 Introduction

In Thailand, Thai native cattle represent around 70% of the country's beef cattle herd (DLD, 2008). They are smaller mature body size and grow at a slower rate compared to European breeds, but they have abilities to tolerate hot and humid conditions, tolerate intense sunshine, resist parasites and utilize poor quality diets of sub-humid tropical zone. Nutritional feeding guidelines for Thai native cattle have not been well defined because of paucity of information on nutrient requirement. In previous reports, energy requirements of Thai native cattle have been studied via respiration calorimetry method (Kawashima et al., 2000; Nitipot et al., 2008; Moonmart et al., 2009; Tangjitwattanachai et al., unpublished data). Several studies indicated that metabolizable energy for maintenance of Thai native cattle are 245 KJ/kgBW$^{0.75}$/d (Kawashima et al., 2000), 484 KJ/kgBW$^{0.75}$/d (WTSR, 2008), 509 KJ/kgBW$^{0.75}$/d (Nitipot et al., 2009) and 532 KJ/kgBW$^{0.75}$/d (Tangjitwattanachai et al., unpublished data). This data did not confirmed NRC (2000) which suggested that *Bos indicus* require about 10% less energy for maintenance than beef breeds of *Bos taurus.* However, the knowledge of energy metabolism in Thailand can not yet be clarified. Greater understanding on energy metabolism and energy utilization of local beef cattle are required so that the animal can utilize feed resources with greater efficiency. Therefore, this current study was focused on determining metabolizable energy requirements for maintenance and growth of Thai native beef cattle to generate equations describing metabolizable energy requirement for maintenance and growth in tropical zone such as Thailand.

3.1.2 Materials and Methods

3.1.2.1 Animals and experimental design

Eighteen yearling male Thai native beef cattle, with an initial body weight of 94.30 ± 16.5 kg and 13 months of age were housed individually in pens with free access to drinking water and mineral block. This study was carried out from April 2007 to August 2007 at Khon Kaen University's research farm at Faculty of Agricuture, Khon Kaen University, Thailand. All animals were treated with Ivermectin (IVOMEC-F, Merck, Rahway, USA) anthelmintic at 1 ml per 50 kg of body weight prior to start of the experiment. Animals were housed in the individual pens and allowed an adaptation period of 2 weeks prior to 136 days period of data collection. In the adaptation period, they were fed *ad libitum* of roughage and 1.5%BW of concentrate. In the experimental period, the animals were blocked by body weight (6 blocks and 3 animals per block). Within each block, the animals were assigned randomly to the three treatments in a randomized complete block design (RCBD). Treatments were levels of metabolizable energy intake according to Chaokaur et al. (2007) recommendation of metabolizable energy for maintenance requirement (M= 450 KJ/kgBW$^{0.75}$/d) as follows; Treatment 1 = 1.3M, Treatment 2 = 1.7M and Treatment 3 = *ad libitum*.

3.1.2.2 Feed preparation and management

The ration of ruzi hay and concentrate (30:70 dry matter basis) was offered throughout the course of feeding trial. The concentrate portion of diet (on dry matter basis) consisted of palm kernel meal (10%), coconut meal (4%), cassava chip (32%), ricebran (22.5%), urea (1%) and mineral (0.5%) (as in Table 3.1.1). Animals were fed twice daily at 08.00 and 16.00 h. Animals were weighed every 2 weeks at the same time of the day (06.00 h) before feed was offered. The weight of each animal was used as the basis for calculating the daily feed allocation for the next 14 days.

Table 3.1.1 Ingredients and chemical composition of feeds

Items	DM basis (%)
Ingredients	
Ruzi grass hay	30.0
Cassava chip	32.0
Rice bran	22.5
Coconut meal	4.0
Palm kernel cake	10.0
Urea	1.0
Mix mineral	0.5
Chemical composition, %	
DM	93.80
CP	10.03
OM	94.68
EE	4.70
NDF	37.13
ADF	23.98
Energy content, MJ/kg DM	
GE	18.02
DE	11.54
ME	10.43

3.1.2.3 Data collection and chemical analysis

1) Digestion trial

Digestion trial period consisted of a 14 day adaptation period and 7 day collection period. The animals were switched to metabolic cage by block for intake, feces and urine samples collection. Daily individual animal feed intake was recorded by weighing the offered and refused quantities. Samples of feed and feed refusal were collected for chemical analysis. Total feces and urine output were weighed and individually homogenized. Urine was collected in the bucket containing 20% sulfuric acid to maintain a pH of 3 and prevent the volatilization of urinary nitrogen. All samples were taken daily in the morning and stored at -18 °c. At the end of period, all samples were thawed; mixed thoroughly and sub-sampled (1 kg of feces and 500 ml of urine) and stored at -18 °c for chemical analysis.

2) Chemical analysis

Feeds, orts and feces were dried at 100 ^{o} C for dry matter calculation and dried at 60 °c for at least 72 h and ground to pass through a 1-mm. screen (Retsch, Model: SM 2000/695 Upm. GmbH&Co.kG Rheinische strabe 36, 42781 Haan. Germany). The composites of feed, orts, urine and feces were taken for gross energy determination with a SHIMADZU auto-calculating bomb calorimeter according to AOAC (1990). Proximate analysis was carried out on the minced samples for dry matter (DM), crude protein (CP), ether extract (EE) and ash according to the methods of AOAC (1990). Contents of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to the methods of Van Soest (1991).

3.1.2.4 Calculation and statistical analysis

Energy content of feed was measured by using data from the digestion trial. Gross energy intake was calculated from gross energy content in feed multiplied by average daily feed intake. Digestible energy intake of each animal was determined as the difference between gross energy intake and output of fecal energy (FE). Metabolizable energy intake (MEI) was calculated as gross energy intake minus feces energy (FE) and urine energy (UE), multiplied by 0.93 to correct for fermentation losses according to ARC (1980) and Liang and Young (1995). Average daily gain of each animal from this study was estimated from a linear regression;

$$Y = a + b\,(X)$$

Where Y values represent weights, X values represent number of days in the experiment and the slope (b) represents the average daily gain for 136 days period following the beginning of treatment according to Liang and Young (1995).

All data were analyzed by ANOVA and differences among treatments means were tested by Duncan's new multiple range test by using PROC GLM of SAS (1999) according to a randomized complete block design (RCBD) as depicted in the following model;

$$Y_{ij} = \mu + \rho_i + \tau_j + \varepsilon_{ij} ;$$

where Y_{ij} is the observed value for a dependent variable on i_j, with μ is overall mean, ρ is the effect of block i, τ is the effect of dietary treatment j and ε is the random experimental error.

Determination of maintenance requirement of metabolizable energy was performed using a long-term feeding trial (Taylor et al., 1986; Luo et al., 2004) and requirements for growth were calculated from the obtained equation. All data (database consisted of 18 animal mean observations from this experiment) were constructed and analyzed to determine metabolizable energy requirement for maintenance and growth by regressing metabolizable energy intake (KJ/kgBW$^{0.75}$/d) against average daily gain (g/kgBW$^{0.75}$/d) as follows;

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

Metabolizable energy requirement for maintenance was determined by calculation assuming that maintenance requirement is the value at which ADG is equal to zero (Y-intercept; *a*) and the slope (*b*) of linear regression of average daily gain on metabolizable energy intake was used to describe metabolizable energy requirement for growth according to the method suggested by McDonald et al. (2002) and Luo et al. (2004).

3.1.3 Results and Discussion

3.1.3.1 Feed intake and energy intake

Feed intake, where expressed in kg of dry matter per day increased with increasing level of metabolizable intake *(P<0.05)* and *ad libitum* level of cattle from this study was 2.84 kgDM per day or estimated approximately 1.71 of maintenance level metabolizable energy intake (KJ/kgBW$^{0.75}$/d). Crude protein intake (g/kgBW$^{0.75}$/d) was higher *(P<0.05)* in beef cattle fed *ad libitum* and 1.7 M than *($P<0.05$)* that cattle fed 1.3 M. Gross energy intake and digestible energy intake were influenced *($P<0.05$)* by levels of metabolizable energy intake and higher *(P<0.05)* in beef cattle fed *ad libitum* and 1.7 M than *($P<0.05$)* that for cattle fed 1.3 M. The highest metabolizable energy intake was 768.86 KJ/kgBW$^{0.75}$/d. The metabolizable energy intake from this study was lower than that reported by Nitipot et al. (2009) (1012.74 KJ/kgBW$^{0.75}$/d), but was higher than the reports of Kaewpila (2010) (738.89 KJ/kgBW$^{0.75}$/d) and Moonmart (2009), who indicated that metabolizable energy intake of Thai native cattle ranged from 500-547 KJ/kgBW$^{0.75}$/d. The increase of metabolizable energy intake from this work resulted in higher average daily gain, which is shown in Table 3.1.2 This result is similar to Clark et al. (2007) and Chaokaur et al. (2008).

3.1.3.2 Average daily gain

Average daily gain (g/kgBW$^{0.75}$/d) was significantly *(P<0.05)* affected by the different metabolizable energy intake. Average daily gain of all animals increased (*P*<0.05) with increasing energy intake. The highest body weight gain (g/kgBW$^{0.75}$/d) was obtained in cattle fed *ad libitum* (average daily gain = 521.20 g/d or 13.48 g/kgBW$^{0.75}$/d) and lowest body weight gain was in cattle fed 1.3 M (average daily gain = 307.52 g/d or 8.83 g/kgBW$^{0.75}$/d) (as in Table 2). The result from this study is slightly higher than reported by Moonmart (2009) who found that average daily gain of Thai native cattle fed at 1.2 of maintenance was about 272.92-283.34 g/d and which was similar to Thai native heifer from report of Chantiratikul and Chumpawadee (2009) (190-410 g/d). When compared with other breeds, the average daily gain of Thai native cattle from this study was lower than Brahman cattle fed under Thailand condition from report of Chaokaur et al. (2009) (237-946 g/d) and Nellore cattle from report of Tedeschi et al. (2002) (920-977 g/d).

Table 3.1.2 Metabolizable energy intake and average daily gain of Thai native beef cattle fed diets containing various metabolizable energy intake

Item	Level of metabolizable energy intake			SEM	Polynomial contrast	
	1.3M	1.7M	*ad libitum*		*L*	*Q*
No.of animal	6	6	6			
Initial weight, kg	92.92	95.17	94.75	2.51	0.617	0.674
Final weight, kg	134.45^{b}	151.75^{ab}	164.72^{a}	6.21	0.006	0.782
Average body weight, kg	113.68^{b}	123.46^{ab}	129.73^{a}	9.06	0.022	0.734
Metabolic body weight, kg	34.75^{b}	36.96^{ab}	38.31^{a}	1.22	0.026	0.728
Feed intake (kgDM/d) *	1.97^{b}	2.54^{a}	2.84^{a}	0.11	0.003	0.37
Energy intake **						
GE intake, KJ/kgBW$^{0.75}$/d	1063.91^{b}	1202.72^{a}	1279.63^{a}	29.17	0.002	0.46
DE intake, KJ/kgBW$^{0.75}$/d	675.41^{b}	795.12^{a}	829.61^{a}	26.02	0.002	0.29
ME intake, KJ/kgBW$^{0.75}$/d	590.83^{c}	713.53^{b}	775.16^{a}	17.15	0.0001	0.21
Energy loss **						
Feces excretion, KJ/kgBW$^{0.75}$/d	388.50^{b}	407.60^{ab}	450.03^{a}	17.83	0.05	0.61
Urine excretion, KJ/kgBW$^{0.75}$/d	21.23	23.49	24.41	1.01	0.09	0.59
FE/GE, %	36.57	33.94	35.19	1.57	0.53	0.29
UE/GE, %	2.27	1.96	1.92	0.13	0.06	0.42
Average daily gain, g/d	307.52^{c}	416.27^{b}	521.20^{a}	33.18	0.0011	0.96
Average daily gain, g/ kgBW$^{0.75}$/d	8.83^{c}	11.26^{b}	13.48^{a}	0.64	0.005	0.89
Energetic efficiency						
DE/GE	0.63	0.65	0.64	0.01	0.022	0.783
ME/GE	0.57	0.60	0.58	0.01	0.021	0.827
ME/DE	0.89	0.90	0.90	0.001	0.154	0.401

* calculated from feeding trial (136 days) and ** calculated from digestion trial (21 days)

^{a,b} within a row, means without a common superscript letter differ *(P<0.05)*

However, this current study demonstrates that Thai native cattle fed higher energy resulted in linear *(P*<0.05*)* increased average daily gain, which is similar to the report of Kirkland and Patterson (2006), who indicated that live-weight gain increased with increasing energy intake, and dry matter intake per live weight gain in steers decreased with increasing energy intake. Moreover, this current study supports the work of Chowdhury and Ørskov (1997), who found that increase in energy intake can improve animal performance but, increasing protein level can not improve growth rate if energy intake was limiting and phases of growth depends on the level of energy supply.

3.1.3.3 Digestibility and energy partition

Energy partition was compared among treatments on the basis of metabolic body weight as shown in Table 3.1.2. Total energy loss in feces and urine were lowest in 1.1 M and highest in *ad libitum* group. This result is in good agreement with Freetly et al. (2008), who found that fecal and urine energy losses followed the same patterns of increase as energy intake of beef cows. Moreover, this study is similar to the report of Clark et al. (2007), who found that fecal and urine energy losses were similar between steers fed *ad libitum* of energy intake and 90% of *ad libitum*, but which was higher *(P<0.05)* than cattle fed lower energy intake. However, energy loss in feces and urine from this current study are in contrast to that reported by Kirkpatrick et al. (1997) and Kurihara et al. (1999), who found that energy loss in feces and urine in cattle offered high energy intake seemed to be greater than cattle fed low energy intake. In comparing other research in Thailand, the energy loss per energy intake from this study follows a similar pattern to that reported by Tangjitwattanachai and Sommart (2010, unpublished data) and Moonmart (2009).

The ratios of DE to GE, ME to GE and ME to DE were not different *(P>0.05)* across all treatments. However, the ratio of ME to DE from this study (0.89-90) is higher than the recommendation of NRC (2000) of 0.82. In comparing with other reports, the ratio of ME to DE from this study is higher than Brahman cattle fed a diet containing energy at 1.4M to *ad libitum* level from report of Chaokaur et al. (2008)(0.86-0.88), but lower than Thai native cattle fed high concentrate from report of Kawashima et al. (2000)(0.89-0.92). Hindrichsen et al. (2003) and Pitroff et al. (2006) suggested that increasing concentrate intake or feeding level can improve energetic efficiency of ME, when compared with animals fed at maintenance level intake.

3.1.3.4 Description of data

The nutrient intake used in database was calculated from nutrient in feed intake of each animal minus nutrient in feed refusal of each animal. Average daily gain of animal was estimated from a linear regression, weights represent by Y values and X values represent the number of days in the experiment. All data was constructed and analyzed to determine metabolizable energy requirement by regression technique.

The summary database of prediction of metabolizable energy requirement for maintenance and gain are shown in table 3.1.3. The average body weight of experimental animals ranged from 88.05-163.00 kg, and metabolic body weight ranged from 28.74-45.62 $kgBW^{0.75}$. Dry matter intake of animals ranged from 1.62-3.76 kgDM/h/d. Metabolizable energy intake ranged from 577.89-859.17 $KJ/kgBW^{0.75}/d$. Average daily gain of animals in this study ranged from 7.35-15.20 $g/kgBW^{0.75}/d$. The mean, standard deviation, minimum and maximum values of data are shown in Table 3.1.3.

Table 3.1.3 Description data of animals and metabolizable energy intake for prediction of metabolizable energy requirements for maintenance and for growth in Thai native beef cattle

Item	n	Mean	SD	Min	Max
Body weight (kg)	18	122.29	21.46	88.05	163.00
Metabolic body weight ($kgBW^{0.75}$)	18	36.67	4.84	28.74	45.62
Feed intake (kgDM/d)	18	2.45	0.56	1.62	3.76
Metabolizable energy intake (KJ/d)	18	25538.03	5860.65	16857.32	39194.09
Metabolizable energy intake ($KJ/kgBW^{0.75}/d$)	18	691.07	87.18	577.89	859.17
Average Daily Gain (g/d)	18	414.99	122.19	254.30	648.20
Average Daily Gain ($g/kgBW^{0.75}/d$)	18	11.19	2.36	7.35	15.20

Max = Maximum, Min = Minimum, SD = Standard deviation

3.1.3.5 Metabolizable energy requirements for maintenance and for growth

Metabolizable energy requirement for maintenance (ME_m) was determined by regression analysis of metabolizable energy intake (MEI, KJ/kg $BW^{0.75}/d$) on average daily gain (ADG, g/kg $BW^{0.75}/d$) (Taylor et al., 1986; Luo et al., 2004). The regression equation developed in this study was highly significant ($P<0.01$) and R^2 value was 0.82. A linear relationship of regressing ADG against MEI of this study was obtained, MEI = $(390.61)_{(39.75)} + (35.42)_{(3.49)}$ ADG (R^2 = 0.8239, N = 18, RMSE = 33.34, $P<0.001$). From this result, due to limited data at the low average daily gain, the straight line obtained in this analysis can be extrapolated to the point of zero average daily gain giving an estimate of metabolizable energy for maintenance (Figure 3.1.1). The result indicates the metabolizable energy requirement for maintenance of 390.61 KJ/kgBW$^{0.75}$/d. Furthermore, metabolizable energy requirement for growth from this study can be estimated 1 g/kg BW$^{0.75}$/d gain of yearling Thai native cattle as 35.42 KJ/kg BW$^{0.75}$/d. The metabolizable energy requirement for growth from this current study is higher than recommendation for Thai native cattle by WTSR (2008) (30.29 KJ/kg BW$^{0.75}$/d), but which less than Brahman cattle from the report of Ferrell et al. (2006), that metabolizable energy requirement for growth of 60.57 MJ/kg at 350 kg of body weight.

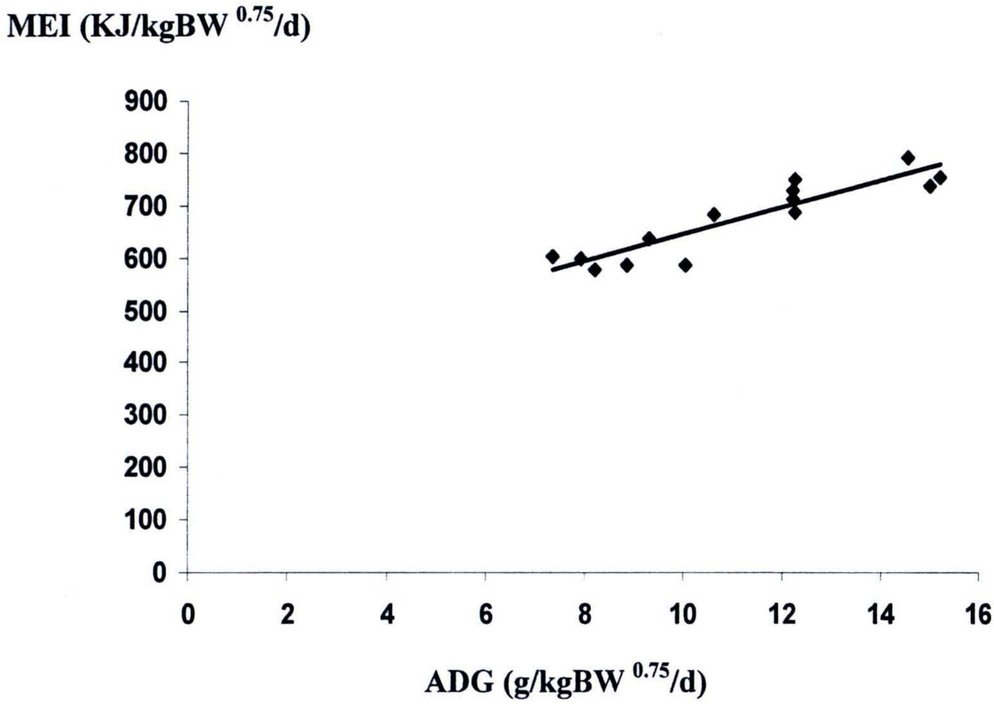

Figure 3.1.1 Relationship between metabolizable energy intake (MEI, KJ/kgBW$^{0.75}$/d) and average daily gain (ADG, g/kgBW$^{0.75}$/d) of Thai native cattle describes equation; MEI = $(390.61)_{(39.75)} + (35.42)_{(3.49)}$ ADG (R^2 = 0.8239, N = 18, RMSE = 33.34, $P<0.001$)

The energy requirement for maintenance from this study is lower than reported of Nitipot et al. (2009) and Moonmart (2009), who found that metabolizable energy requirement for maintenance of Thai native cattle fed under tropical conditions in Thailand was 509 KJ/kgBW$^{0.75}$/d and 526 KJ/kgBW$^{0.75}$/d, respectively. Moreover, this current result is lower than suggested for Thai native cattle from WTSR (2008) (484 KJ/kgBW$^{0.75}$/d). In previous studies, Kawashima et al. (2000) investigated metabolizable energy requirement for maintenance of Thai native cattle by face-mask method, which was under-estimated (245 KJ /kgBW$^{0.75}$/d). Nitipot et al. (2009) and Tangjitwattanachai and Sommart (2010, unpublished data) suggested that metabolizable energy for maintenance of Thai native cattle using indirect flow-through calorimeter with head box was 509 KJ/kgBW$^{0.75}$/d and 532 KJ/kgBW$^{0.75}$/d, respectively. However, the work of Nitipot et al. (2009), Tangjitwattanachai and Sommart (2010, unpublished data) and Kawashima et al. (2000) also does not support that other breeds of tropical zone, such as Brahman cattle in Thailand from report of Chaokaur et al. (2007) (458 KJ/kgBW$^{0.75}$/d) and Tuli cattle from report of Ferrell and Jenkin (1998)(417.56 KJ/kgBW$^{0.75}$/d).

In comparing with *Bos indicus* cattle, it was found that metabolizable energy requirement for maintenance of this study was lower than Brahman crossbred from the report of Ferrell and Jenkin (1998) (488 KJ/kgBW$^{0.75}$/d), Nellore steers from the report of Tedeschi et al. (2002) and the report of Chizzotti et al. (2008) (498 KJ/kgBW$^{0.75}$/d and 456 KJ/kgBW$^{0.75}$/d, respectively). When compared with *Bos taurus* cattle, found that this current study was lower than suggested for beef cattle of AFRC (1990) (459 KJ/kgBW$^{0.75}$/d), Japanese black cattle from AFFRCS (1999) (439 KJ/kgBW$^{0.75}$/d) and temperate breeds from the recommendation of NRC (1976) (540 KJ/kgBW$^{0.75}$/d). Metabolizable energy requirement for maintenance of Thai native from this current study is lower than for Simmental from the report of Laurenz et al. (1991)(536 KJ/kgBW$^{0.75}$/d), for growing Herefords from the report of Birkelo et al.(1991)(496 KJ/kgBW$^{0.75}$/d) and for Holstein Friesian from the report of Unsworth et al.(1991) (670 KJ/kgBW$^{0.75}$/d). These findings support the hypothesis of NRC (2000), which indicates that energy requirement for maintenance of *Bos indicus* is assumed lower than for *Bos taurus* cattle. In Thailand, there is still limited information on energy requirement of growing Thai native cattle. Estimation of metabolizable energy requirement for maintenance of this study required extrapolation outside of the data set owing to a lack of data points close to the x-axis. The regression equations developed were based on a wide range of nutrients intake and average daily gain. However, metabolizable energy for maintenance estimates vary widely and it is not yet clear, because many factors influence energy requirement such as biological type, sex, stage and environmental conditions (NRC, 2000; Luo et al., 2004). More energy research is needed to better define nutrients requirement for Thai native beef cattle.

3.1.3 Conclusion

Feed intake increased linearly with increasing level of metabolizable intake. Dietary energy intake influenced energy loss in feces, but had no effect on energy loss in urine. Urine energy loss per gross energy intake decreased with increasing energy intake. The average daily gain of Thai native cattle from this study ranges from 307.52 to 521.20 g/d or 8.83 to 13.48 g/kgBW $^{0.75}$/d, and increased linearly ($P<0.05$) with increasing metabolizable energy intake.

The results of this present study indicate that metabolizable energy for maintenance of growing Thai native cattle is 390.61 KJ/kgBW$^{0.75}$/d. Metabolizable energy requirements for growth 1 g/kg BW$^{0.75}$/d is 35.42 KJ/kgBW$^{0.75}$/d. The results are lower than many reports and recommendation by WTSR of Thailand. However, our findings support the hypothesis by NRC that *Bos indicus* might have lesser maintenance requirement than *Bos taurus*. The equations from this study were construct and analyzed from a small database, therefore more energy research is needed for increasing accuracy and precision of feeding standards in Thailand.

3.2 Part 2: METABOLIZABLE ENERGY REQUIREMENT FOR MAINTENANCE AND GROWTH OF YEARING THAI NATIVE CATTLE BY USING BALANCE TRIAL METHOD

3.2.1 Introduction

Over the last decade, the NRC and ARC guidelines have been used to evaluate feeding plans in several parts of the world (Tedeschi et al., 2002; Chizzotti et al., 2008). Nevertheless, the energy requirement recommendation by NRC was developed and based on temperate beef cattle. Patle and Mudgal (1975), Carsten et al. (1989) and NRC (2000) suggest that *Bos indicus* cattle required 10% less maintenance energy than *Bos taurus* cattle. This hypothesis is supported by numerous researchers, who revealed that *Bos indicus* cattle can perform as well or better in restrictive nutritional conditions than *Bos taurus* cattle (Frisch and Vercoe, 1982; Hotovy et al., 1991; Ferrell and Jenkins, 1998; Chizzotti et al., 2008). However, the facts regarding energy metabolism are not yet clear, because energy requirement is influenced by many factors such as breed, age, seasonal, environment conditions and biological status of animal.

Currently, the lack of data to assess feeding programs is the main problem facing beef cattle development. Prior studies indicate that there is wide variation in energy requirement estimations. Kawashima et al. (2000), Nitipot et al. (2009) and Chaokaur et al. (2009) have studied the issue via respiration calorimetry method, but the energy recommendation of beef cattle in Thailand has still not been well defined and is not constant, because they were developed from small databases and very little research has been conducted so far to determine nutrients requirements. Additional energy research is urgently required to better identify nutrients requirement for beef cattle. Therefore, this study aimed to determine energy requirements and energetic efficiency of Thai native beef cattle, to be used as basis for developing a beef feeding system for Thailand.

3.2.2 Materials and Methods

3.2.2.1 Animals and experimental design

This study was conducted at Khon Kaen University's research farm at Faculty of Agricuture, Khon Kaen University, Thailand from April 2007 to August 2007. Twenty-four growing male Thai native beef cattle, with an average initial weight of 92.56 ± 15.4 kg and 13 months of age were housed individually in pens with free access to drinking water and mineral block. All cattle were treated to remove parasites by using Ivermectin (IVOMEC-F, Merck, Rahway, USA) and vaccination before the start of the experiment. Animals were housed in the individual pens and allowed an adaptation period of 2 weeks prior to 136 days of data collection period. They were fed *ad libitum* of roughage and 1.5%BW of concentrate in the adaptation period. After adaptation period, all animals were separated into 2 groups. One group of 6 animals were the initial group, which was slaughtered at the start of the experiment to provide data on body composition. The rest of the animals (18 animals) were blocked by body weight (6 blocks and 3 animals per block). Within each block, the animals were allocated randomly to one of three treatments according to a randomized complete block design (RCBD). Treatments were levels of metabolizable energy intake as follows; Treatment 1 = 1.3 M, Treatment 2 = 1.7 M and Treatment 3 = *ad libitum* (assuming M (maintenance) = 450 KJ/kgBW$^{0.75}$/d, as referred to in the report of Chaokaur et al. (2007)). At the end of the experiment, all these animals were slaughtered to determine body composition. Energy retention was calculated from the difference of energy in initial group and energy in final group according to the method of Lofgreen (1968).

3.2.2.2 Feed preparation and management

The experimental diet (total mixed ration of ruzi hay and concentrate in 30:70 dry matter basis) was offered throughout the course of feeding trial. The concentrate portion consisted of palm kernel meal (10%), coconut meal (4%), cassava chip (32%), rice bran (22.5%), urea (1%) and mixed mineral (0.5%). The ingredients of diet and chemical composition are shown in Table 3.2.1. All animals were fed twice every day at 08.00 and 16.00 h. Animals were weighed every 2 weeks at the same time of the day (06.00 h) before being offered feed. The weight of each animal was used as the basis for calculating the daily feed distribution for the next 2 weeks.

Table 3.2.1 Ingredients and chemical composition of feeds

Items	DM basis (%)
Ingredients	
Ruzi grass hay	30.0
Cassava chip	32.0
Rice bran	22.5
Coconut meal	4.0
Palm kernel cake	10.0
Urea	1.0
Mix mineral	0.5
Chemical composition , %	
DM	93.80
CP	10.03
OM	94.68
EE	4.70
NDF	37.13
ADF	23.98
Energy content, MJ/kg DM	
GE	18.02
DE	11.54
ME	10.43

3.2.2.3 Data collection and chemical analysis

1) Digestion trial

Daily individual feed intake was recorded by weighing the offered and refused quantities. Samples of feed and feed refusal were collected once every 2 weeks. Feeds and orts were dried at 100 ^{o}C to calculated dry matter and dried at 60 ^{o} C and ground to pass a 1-mm screen (Retsch, Model: SM 2000/695 Upm. GmbH&Co.kG Rheinische strabe 36, 42781 Haan. Germany), and proportionally subsampled to a composite sample. The composite samples (feeds and orts) were stored until chemical analysis.

The digestion trial period consisted of a 14 day adaptation period and 7 day collection period. The animals were switched to metabolic cage by block for feces and urine collection. Total feces and urine quantities were daily recorded in the collection period. Feces were sampled to about ~ 20% of total output and collected in plastic bags before being stored at -18 °c. Urine was collected in plastic buckets containing 20% H_2S0_4 (~ 150 ml) to maintain pH below 3.0 and a 500 ml sample was taken daily. At the end of the period, samples of feces and urine were thawed, mixed thoroughly and sub-sampled (feces ~ 2 kg and urine ~ 500 ml). The composites of urine were stored at -18 °c, the feces samples were oven-dried at 60 °c for at least 72 h and ground to pass through a 1-mm screen for later analysis.

2) Slaughter technique for body composition determination and carcass trait

Before slaughter, Animals are standing without feed and water at least for 12 h according to Lofgreen (1968). At slaughter, all animals were stunned and killed by exsanguinations. All organ parts were manually separated into individual components according to method of Ferrell and Jenkins (1998). The weights of non carcass, warm carcass, stomach organs (cleaned digestive complex), and visceral organ were recorded. Empty body weight was computed as the difference between slaughter weight and digestive tract contents. The carcass was split into longitudinal halves with band saw. The left carcass was weighed and separated into bone and muscle tissue. Non carcass parts (head, hide, shank, tail) were separated into bone, muscle and hide. Hide was cut into small pieces before grinding twice through a sieve plate with holes 2.0 mm in diameter and subsequent sampled to approximately 10% of total hide. Bone was sawn into small pieces and ground three times through a sieve plate with holes 2.0 mm in diameter before proportionally sampling approximately 10% of total bone. The muscle and tissue from each organ was ground separately twice by food processor. A random sample of approximately 500 g, was obtained for each component from the homogenized ground materials, placed in a sealed plastic bag and store at -18 °c before being analyzed for chemical composition (crude protein, ether extracts and ash) according to the method of Chizzotti et al. (2007).. Protein was analyzed by macro Kjeldahl N procedure, fat was analyzed by Soxhlet extraction apparatus for at least 18 h and ash was analyzed until complete combustion in a muffle furnance at 600 °c according to the method of AOAC (1990). The right carcass was chilled at 3 °c for at least 24 h, and then the following were determined and recorded the data of rib eye area according to Bogs and Merkel (1993), fat thickness, percentage of kidney, pelvic and heart (%KPH) fat and yield grade according to USDA quality grading standards for beef carcass. The right carcass was then divided into eight primal cuts (chuck, brisket, rib, plate, flank shortloin, sirloin and round) according to USDA (1997). Subprimal cuts were weighed and recorded. After that, all subprimal cuts were divided into retail cuts of Thai style cutting. All parts of these cuts were weighed and recorded before sampling approximately 1 kg of each part (longissimus dorsi, proas major, semimembranosus, gastrocnemius and longissimus thoracis) for consumer acceptablility test and chemical analysis. Meat (longissimus dorsi and semimembranosus) were sampled again and analyzed for fatty acid composition by Gas chromatrographic analysis according to the method of Folch et al. (1957) and Morrison and Smith (1964). Lately, Meat samples of each part were sampling to cook for consumer acceptablility evaluation according to the method of Marino et al. (2006). A panel of one hundred (non-trained) assessed a profile composed of beef odour intensity (1 to 4 point); tenderness, juiciness, flavour and overall acceptablility. A score of 1 stood for high odour, flavor and very acceptable, score of 4 stood for low odour, flavor and not acceptable. For chemical analysis, the meat samples of each part were randomly sub-sampled in triplicate for moisture crude protein, ether extract and ash according to method of AOAC (1990).

3) Chemical analysis

The composite of feeds, ort, feces and urine were taken for chemical composition analysis. Dry matter (DM), crude protein (CP), ether extracts (EE), and ash contents of feeds, ort, and feces were determined according to method of AOAC (1990). The nitrogen (N) content of urine was determined with Kjeldahl N procedure according to method of AOAC (1990). Neutral detergent fiber (NDF) was analyzed according to method of Van Soest (1991). Acid detergent fiber (ADF) was analyzed according to method of Goering and Van Soest (1970). Gross energy (GE) contents of feeds orts and feces were determined in a SHIMADZU auto-calculating bomb calorimeter (SHIMADZU CA-4PJ, SHIMADZU COPORATION, JAPAN).

3.2.2.4 Calculation and statistical analysis

Gross energy intake (GEI) was calculated from gross energy contents in feed multiplied by average daily feed intake. Digestible energy intake (DEI) of each animal was determined as the difference between gross energy intake and output of fecal energy (FE). Metabolizable energy intake (MEI) was calculated as gross energy intake minus feces energy (FE) and urine energy (UE), multiplied by 0.93 to correct for fermentation losses according to ARC (1980) and Liang and Young (1995).

Energy retention was calculated from the difference of energy retained in initial group and energy retained in final group. Energy retained was determined by assuming the caloric values of fat and protein to be 9367 kcal/kg of fat (Blaxter and Rook, 1953) and 5686 kcal/kg of protein (Garrette, 1958).

All data (feed intake, body composition, carcass trait, organ weight and gain data) were analyzed with general linear models procedure and treatment means were compared by Duncan's new multiple range test (SAS, 1996) according to a randomized complete block design shown by the following model;

$$Y_{ij} = \mu + \rho_i + \tau_j + \varepsilon_{ij} ;$$

where Y_{ij} is the observed value for a dependent variable on i_j, with μ is overall mean, ρ is the effect of block i, τ is the effect of dietary treatment j and ε is the random experimental error.

Linear and quadratic contrast of treatment mean was made to evaluate whether first and second order relationships existed between dependent variables and feeding animals increasing levels of feeding at maintenance level (M).

The metabolizable energy requirements for maintenance and gain were estimated by using the Proc REG procedure of SAS according to Luo et al. (2004) and McDonald et al. (2005) and Pond et al. (2005). All data were constructed and analyzed to determine the metabolizable energy requirements for maintenance and gain by regressing energy retention (ER, KJ/kgEBW$^{0.75}$/d) against metabolizable energy intake (MEI, KJ/kgEBW$^{0.75}$/d) as follows;

$$ER = a + b\,MEI$$

From the obtained equations, metabolizable energy requirement for maintenance was determined by calculation assuming that the maintenance requirement is the value at which energy retention is equal to zero (Y-intercept; *a*) and the slope (*b*) was the partial efficiency of use of ME to NE according to the method suggested by Garrette (1980), Tedeschi et al. (2002) and Luo et al. (2004).

The net energy requirement for maintenance or energy for basal metabolism was determined by regressing log heat production (HE, KJ/kgEBW$^{0.75}$/d) against metabolizable energy intake (MEI, KJ/kgEBW$^{0.75}$/d). An exponential regression was used to describe the relationship between log heat production and metabolizable energy intake as follows;

$$HE = a + b \text{ x daily MEI}$$

From the obtained equations, the net energy requirement for maintenance calculated as the metabolizable energy intake at which heat production is equal to metabolizable energy intake according to the method suggested by Lofgreen and Garrette (1968) and Ferrell and Jenkins (1998).

3.2.3 Results and Discussion

3.2.3.1 Feed intake and energetic efficiency

Feed intake and energy intake are shown in Table 3.2.2. The results show that daily feed intake increased linearly *(P<0.01)* with increasing level of metabolizable energy intake. Feed intake, expressed as kg dry matter intake per day of cattle fed 1.7M and *ad libitum* was higher (*P*<0.05) than that for cattle fed 1.3M, but no differences were observed between 2 treatments (1.7M vs. *ad libitum*). Metabolizable energy intake was increased with increasing dry matter intake. Metabolizable energy intake ranged from 590.83 to 768.86 KJ/kgBW$^{0.75}$/d. Energy output from feces was lowest in 1.3M and highest in *ad libitum* group, but there were no difference *(P>0.05)* between 1.7M and *ad libitum* group. Likewise, energy intake did not affected *(P>0.05)* energy loss in urine. The ratio of energy loss in feces per gross energy intake were not different *(P>0.05)* across all treatments, but the energy loss in urine per energy intake declined *(P<0.01)* with increasing energy intake. This study agrees with the report of Freetly et al. (2008), who found that energy losses in feces and urine followed the same patterns of increase as energy intake of beef cows. Kirkpatrick et al. (1997) and Kurihara et al. (1999) found that energy loss in feces and urine in cattle offered high energy intake seemed to be greater than cattle fed low energy intake. When compared with other research in Thailand, the energy loss per energy intake from this present study follows a similar pattern to that reported by Tangjitwattanachai and Sommart (2010, unpublished data) and Moonmart (2009).

Heat production and energy retention have a positive linear response (P<0.01) as the energy intake increased. This data supports the report of Yan et al. (2006), who found that if energy intake increased, the energy retention in tissue and energetic efficiency are increased. These findings are similar to reports of several researchers (Pittroff et al., 2006; Olson et al., 2008), which indicate that high levels of energy intake lead to higher rates of gain and energy retention. This brings about a reduction in maintenance costs because of higher feed efficiencies (Trenkle and Marple, 1983; Liang and Young, 1995).

Table 3.2.2 Energy partition and energetic efficiency of Thai native beef cattle fed diets containing various metabolizable energy intake

Item	Levels of energy feeding			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Number animal, head	6	6	6			
Initial weight, kg	92.92	95.17	94.75	2.51	0.617	0.674
Final weight, kg	134.45^{b}	151.75^{ab}	164.72^{a}	6.21	0.006	0.782
Average body weight, kg	113.68^{b}	123.46^{ab}	129.73^{a}	9.06	0.022	0.734
Metabolic body weight, kg	34.75^{b}	36.96^{ab}	38.31^{a}	1.22	0.026	0.728
Feed intake (kgDM/d) *	1.97^{b}	2.54^{a}	2.84^{a}	0.11	0.003	0.37
Energy intake **						
GE intake, KJ/kgBW$^{0.75}$/d	1063.91^{b}	1202.72^{a}	1279.63^{a}	29.17	0.002	0.37
DE intake, KJ/kgBW$^{0.75}$/d	675.41^{b}	795.12^{a}	829.61^{a}	26.02	0.002	0.29
ME intake, KJ/kgBW$^{0.75}$/d	590.83^{c}	713.53^{b}	775.16^{a}	17.15	0.001	0.21
Energy loss **						
Feces excretion, KJ/kgBW$^{0.75}$/d	388.50^{b}	407.60^{ab}	450.03^{a}	17.83	0.05	0.61
Urine excretion, KJ/kgBW$^{0.75}$/d	21.23	23.49	24.41	1.01	0.09	0.59
FE/GE, %	36.57	33.94	35.19	1.57	0.53	0.29
UE/GE, %	2.27	1.96	1.92	0.13	0.06	0.42
Heat production, KJ/kgBW$^{0.75}$/d	517.42^{b}	594.77^{a}	637.61^{a}	17.91	0.006	0.433
Energy retention, KJ/kgBW$^{0.75}$/d	73.41^{b}	118.76^{a}	137.55^{a}	8.92	0.005	0.452
Average daily gain, g/d	307.52^{c}	416.27^{b}	521.20^{a}	33.18	0.0011	0.96
Energetic efficiency						
DE/GE	0.63	0.65	0.64	0.01	0.022	0.783
ME/GE	0.57	0.60	0.58	0.01	0.021	0.827
ME/DE	0.89	0.90	0.90	0.001	0.154	0.401

* calculated from feeding trial (136 days) and ** calculated from digestion trial (21 days)

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

3.2.3.2 Average daily gain

Daily weight gain of all animals increased *(P<0.05)* with increasing energy intake (see also in Table 3.2.2). These results demonstrate that growth performance can be improved by increasing energy intake, which is supported by report of Kirkland and Patterson (2006), who indicated that live-weight gain increased with increasing energy intake and dry matter intake per live weight gain in steers decreased with increasing energy intake. This current study supports the work of Manninen et al. (2010), who found that the *ad libitum* feeding has generally increased daily weight gain, carcass fat score and improved the growth rate when compared with restricted feeding, in contrast with the suggestion from Hornick et al. (2000), that the restricted feeding or low nutritional planes may decrease metabolic body rate and the maintenance energy requirement of beef cattle. However, Chowdhury and Ørskov (1997) indicated that increase in energy intake can improve animal performance but increasing protein level can not improve growth rate if energy intake was limiting and that phase of growth depends on the level of energy supply.

3.2.3.3 The Body composition and body component gain

The body composition and rate of body component gain are shown in Table 3.2.3 The average empty body weight (EBW) of baseline group was 68.56 kg, percentage of fat and protein in empty body (EB) were 8.51% and 17.51% respectively, and calculated energy retained in the body was 514207 KJ or 7500 KJ/kg of EBW (~1.75 Mcal/kg of EBW).

As for data at slaughter, EBW and fat component in EB linearly *(P<0.05)* increased with increasing metabolizable energy intake. The percentage of fat in EB (empty body fat, EBF) in cattle fed 1.7M and *ad libitum*, were higher *(P<0.05)* than 1.3M, but there was no difference *(P>0.05)* between 1.7M and *ad libitum* group. The fat component ranged from 8.94-12.74% of EB, which was lower than EBF of temperate breeds from the report of Ferrell and Jenkins (1998) such as Hereford (24.10 %), Angus (17.10%) and Piedmontese cattle (18.01 %).

Table 3.2.3 Empty body composition and empty body component gain of Thai native beef cattle fed diets containing various metabolizable energy intakes

Item	Levels of energy feeding			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Body composition of the initial group						
Empty body weight, kg		68.56				
% Empty body fat		8.51				
% Empty body protein		17.51				
Empty body protein, kg		12.01				
Empty body fat, kg		5.83				
Energy in body, KJ		514207				
Body composition of the final group						
Final empty body weight, kg	111.02[b]	126.20[ab]	136.36[a]	5.94	0.021	0.536
Final empty body weight, $kg^{0.75}$	34.14[b]	37.58[ab]	39.75[a]	1.35	0.025	0.507
Average empty body weight, kg	89.79[b]	97.38[ab]	102.46[a]	5.94	0.021	0.536
Average empty body weight, $kg^{0.75}$	29.17[b]	31.00[ab]	32.20[a]	1.35	0.025	0.507
% Empty body fat	8.94[b]	11.86[a]	12.74[a]	0.59	0.007	0.192
% Empty body protein	18.39[a]	17.97[ab]	17.91[b]	0.16	0.342	0.052
Empty body fat, kg	9.92[b]	14.97[a]	17.37[a]	1.07	0.0005	0.295
Empty body protein, kg	20.42[b]	22.67[ab]	24.42[a]	1.03	0.024	0.783
Energy retention, KJ/d	2649.75[b]	4498.64[a]	5496.38[a]	452.51	0.001	0.403
Energy retention, KJ/ kg $EBW^{0.75}$ / d	90.83[b]	145.12[a]	170.69[a]	11.46	0.0007	0.250
Rate of empty body component gain						
Fat gain, g/d	30.07[b]	67.21[a]	84.85[a]	7.92	0.0005	0.295
Protein gain, g/d	61.33[a]	77.38[ab]	91.25[a]	7.59	0.024	0.783
Energy gain, KJ/d	2649.75[b]	4498.64[a]	5496.38[a]	452.51	0.001	0.403
% of fat energy deposition	44.69[b]	58.87[a]	60.51[a]	2.75	0.001	0.094
% of protein energy deposition	55.31[a]	41.13[b]	39.49[b]	2.41	0.001	0.094

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

However, the range of EBF from this study is similar to other researchers (Liang and Young, 1995; Fiems et al., 2005; Chizzotti et al., 2008), who found that the EBF in beef cattle varies from 7.06-36.16%. The protein component tended to increase if metabolizable energy intake decreased, but there was no *(P<0.05)* difference among the 1.3M and 1.7M group. This trend is similar to that reported by Old and Garrette (1985), who showed that the ration of protein component in body decreased from 18.8% to 16.7% in Hereford steers fed high protein and energy diet, while the fat component in body increased. The results agree with the report of Wildman et al. (1986), who studied the effect of age on body composition in young calves and found that body protein portion declined from 18.04 % in weaned animals to 17.84% in the young animals, in contrast with the fat portion which rose from 6.82 % in weaned animals to 15.32% in the young animals. However, the empty body fat (EBF) and empty body protein (EBP) are different because rate and composition of tissue accretion may be controlled by age, physiological state, energy intake and hormonal status (Bergen and Merkel, 1991; Owens et al., 1995).

There is a linear *(P<0.05)* effect of increasing energy gain and energy retention with increasing metabolizable energy intake. The highest energy retention was 170.69 KJ/kgEBW$^{0.75}$/d, which was in cattle fed *ad libitum* intake. Efficiency of fat accretion increased with increasing energy intake, but the efficiency of protein accretion decreased with increasing energy intake. This result indicates that the efficiency of fat accretion expressed as a percentage of energy retention is the converse of protein accretion. Byers (1980), Old and Garrette (1987) and Slabbert et al., (1992) implied that restricting energy intake reduced fat accretion, but can increase the protein per fat ratio of EBW. In addition, Perry et al. (1991) and Rumsey et al. (1992) reported that the fat mass had increased with age or weight, but fat mass accumulated during the background period varied with energy intake. However, these results support the concept that animals with faster rates of gain and fed *ad libitum* will accrete more fat and less protein (Hick et al., 1990; Gill et al., 1993; Ferrell and Jenkins, 1994; Owen et al., 1995).

3.2.3.4 Metabolizable energy requirement for maintenance

The metabolizable energy requirement for maintenance (ME_m) was estimated by regressing energy retention (ER, KJ/kgEBW$^{0.75}$/d) against metabolizable energy intake (MEI, KJ/kgEBW$^{0.75}$/d). The regression equation developed was highly significant (P<0.01) and R^2 value was 0.91. The results are shown graphically in figure 3.2.1. Because of limited data at the low of energy retention, the straight line obtained in this analysis can be extrapolated to the point of zero energy retention giving an estimate of ME_m. This data indicates that ME_m is 485.47 KJ/kgEBW$^{0.75}$/d or 405.79 KJ/kgBW$^{0.75}$/d, which is described in the equation of ER = $(0.41)_{(0.03)}$ MEI - $(199.58)_{(27.74)}$ (R^2 = 0.9134, N = 18, RSD = 3.3331, *P<0.001*).

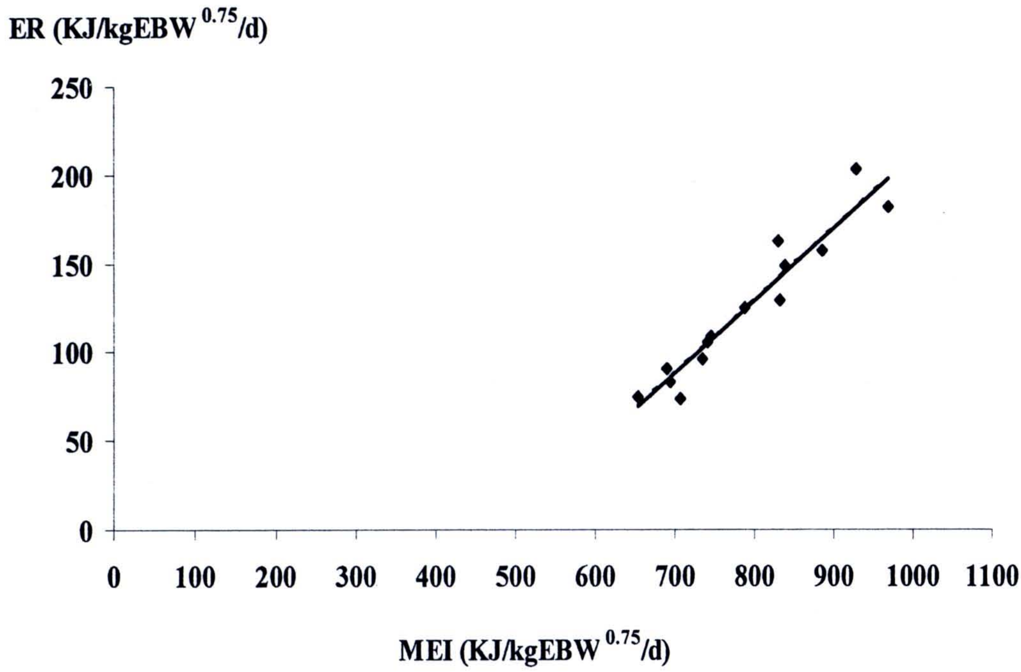

Figure 3.2.1 Relationship between energy retention (ER, KJ/kgEBW$^{0.75}$/d) and metabolizable energy intake (MEI, KJ/kgEBW$^{0.75}$/d) of Thai native cattle described by equation; ER = $(0.41)_{(0.0349)}$ MEI - $(199.58)_{(27.74)}$ (R^2 = 0.9134, N = 18, RSD = 3.3331, *P<0.001*)

The ME_m from this current study was lower than that reported by Nitipot et al. (2009) and Moonmart (2009), who studied ME_m of Thai native cattle via respiration chamber and found that it was 509 KJ/kgBW$^{0.75}$/d and 526 KJ/kgBW$^{0.75}$/d, respectively. Furthermore, this current result is lower than that suggested for Thai native cattle by WTSR (2008) (484 KJ/kgBW$^{0.75}$/d). In prior research, Kawashima et al. (2000) studying ME_m via respiration face-mask method suggested that Thai native cattle required ME_m ~245 KJ /kgBW$^{0.75}$/d, which is lower than several studies (Moonmart, 2009; Nitipot et al., 2009 and Tangjitwattanachai and Sommart, unpublished data). However, data from previous research in Thailand does not agree with *Bos indicus* cattle research in tropical zone, such as Tuli cattle in South-America from the report of Ferrell and Jenkin (1998) (417.56 KJ/kgEBW$^{0.75}$/d) and Brahman cattle in Thailand from the report of Chaokaur et al. (2007) (458 KJ/kgBW$^{0.75}$/d). When comparing with *Bos indicus* cattle, ME_m of this study is slightly lower than Brahman crossbred from the report of Ferrell and Jenkin (1998) (488 KJ/kgBW$^{0.75}$/d) and Nellore steers from report of Tedeschi et al. (2002) (498 KJ/kgEBW$^{0.75}$/d). When comparing with *Bos taurus* cattle, this study is lower than suggested for Japanese black cattle from AFFRCS (1999) (439 KJ/kgBW$^{0.75}$/d), temperate breeds from the recommendation of NRC (1976) (540 KJ/kgBW$^{0.75}$/d), Simmental beef cattle from the report of Laurenz et al. (1991) (536 KJ/kgBW$^{0.75}$/d) and Red Poll from the report of Solis et al.(1991) (705.08 KJ/kgBW$^{0.75}$/d). These findings support the assumption of NRC (2000), which suggests that energy requirement for maintenance of zebu cattle is assumed to be lower than temperate beef cattle.

In Thailand, there is still limited data on energy requirements, therefore estimation of ME_m in this study required extrapolation outside of the data set due to a lack of data points close to the x-axis. Additional energy research is required to better define nutrients requirement for Thai native beef cattle.

3.2.3.5 Net energy requirement for maintenance

The net energy requirement for maintenance (NE_m) was estimated by regressing log heat production (HE, KJ/kgEBW$^{0.75}$/d) against metabolizable energy intake (MEI, KJ/kgEBW$^{0.75}$/d). The regression equation shows high R^2 value (0.95). The results are shown graphically in figure 3.2.2. The linear relationship of regressing HE against MEI was obtained, HE = $(0.0004)_{(0.00002)}$ MEI + $(2.5212)_{(0.0199)}$ (R^2 = 0.9461, N = 18, RSD = 0.0003, $P<0.001$). From this equation, the NE_m can be calculated as the antilog of the intercept, which is 332.05 KJ/kgEBW$^{0.75}$/d. The efficiency of metabolizable energy for maintenance (k_m) of this current study can be calculated as NE_m divide by ME_m, which is 0.68.

The NE_m from this study is slightly higher than that for temperate breed of cattle (NE_m of 322.16 KJ/kgBW$^{0.75}$/d) reported by Lofgreen and Garrette (1968), the NE_m was usually used by the NRC (2000), and Nellore cattle from report of Tedeschi et al. (2002) (323 KJ/kgBW$^{0.75}$/d). In comparison to several reports from Thailand, the NE_m from this study is higher than reported by Chaokaur et al. (2008), who reported that NE_m of Brahman cattle was 289 KJ/kgBW$^{0.75}$/d and Thai native cattle from the report of Nitipot et al. (2009) (281 KJ/kgBW$^{0.75}$/d). These findings show that Thai native cattle require energy for basal metabolism close to *Bos taurus* cattle.

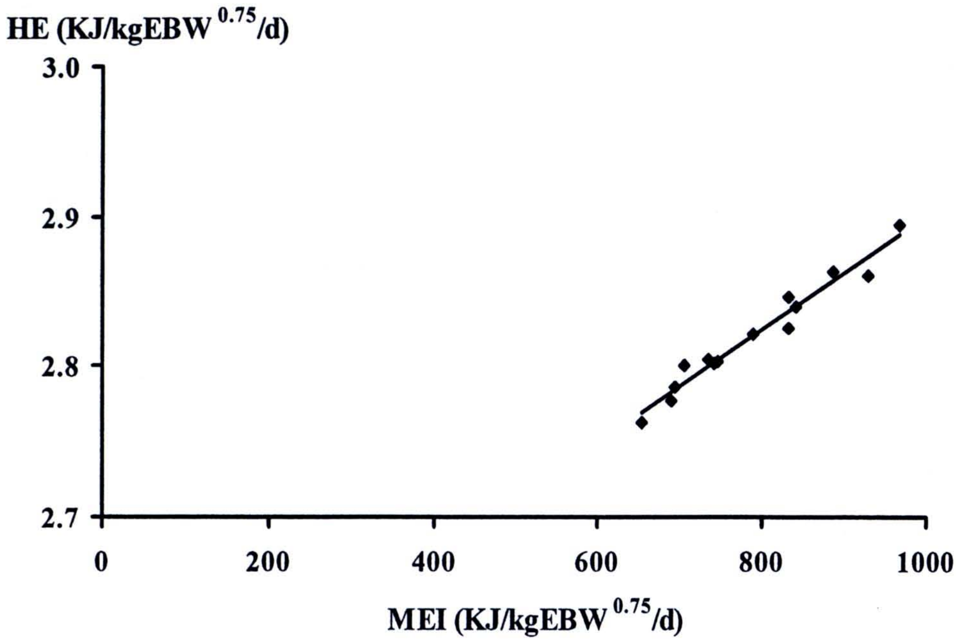

Figure 3.2.2 Relationship between log heat production (HE, KJ/kgEBW$^{0.75}$/d) and metabolizable energy intake (MEI, KJ/kgEBW$^{0.75}$/d) of Thai native cattle describes equation; HE = $(0.0004)_{(0.00002)}$ MEI + $(2.5212)_{(0.0199)}$ (R^2 = 0.9461, N = 18, RSD = 0.0003, $P<0.001$)

3.2.3.6 Energetic efficiency

According to the linear relationship of regressing HE against MEI the follows equation was obtained, HE = (0.0004) $_{(0.00002)}$ MEI + (2.5212) $_{(0.0199)}$ (R^2 = 0.9461, N = 18, RSD = 0.0003, *P<0.001*). The efficiencies of ME utilization for maintenance (k_m) of this current study can be calculated as NE_m divide by ME_m, which is 0.68. This is similar to k_m reported by Ferrell and Jenkins (1998) (0.65), Malaysian native cattle as Kedah Kelantan from reported by Liang and Young (1995) (0.64) and Hereford steer from reported by Fox et al., (1972) (0.66). However, it is slightly lower than Nellore steers from the report of Tedeschi et al. (2002) and Chizzotti et al., (2008) (0.69-0.71). When compared with the other research in Thailand, the k_m from this study is higher than reported by Tangjitwattanachai et al. (2009), who studied on the k_m values by using meta-analysis method and suggested that the k_m of *Bos indicus* cattle was 0.64, which was higher (9.38%) than that of *Bos taurus* cattle.

From the linear relationship of regressing ER against MEI was obtained the equation, ER = (0.41) $_{(0.03)}$ MEI - (199.58) $_{(27.74)}$ (R^2 = 0.9134, N = 18, RSD = 3.3331, *P<0.001*), the efficiencies of ME utilization for growth (k_g) can be estimated from the slope of the linear regression of ER to MEI, with energy retention above zero. The k_g of this current study was 0.41, which was lower than the suggestion of ARC (1980) (0.44) and Nellore steer from the report of Tedeschi et al. (2002) (0.45-0.49) and Chizzotti et al., (2008) (0.51-0.54), but higher than Angus cattle and Hereford cattle from report of Ferrell and Jenkins (1998) (0.32 and 0.39) and Kedah Kelantan from the report of Liang and Young (1995) (0.30). When compare with other reports in Thailand, the k_g of this present study is lower than Brahman cattle from the work of Chaokaur et al., (2008), (k_g of 0.53) and Tangjitwattanachai et al. (2009), who studied on the k_g values by using meta-analysis method and suggested that the k_g of *Bos indicus* cattle was 0.51. However, energetic efficiency remains unclear. Consequently, the future research may be focused on the comparison of breed, age, stage and feeding practice on nutrient utilization in beef cattle. Greater understanding of nutrient utilization is required with the purpose using animal feed resources with maximum efficiency.

3.2.3.7 Carcass trait

1) Carcass composition

The carcass composition is shown in Table 3.2.4. Non carcass components except for tail and shank were not (P>0.05) affected by increasing energy intake. Tail and shank of cattle fed 1.3M were higher (P<0.05) than that of cattle fed 1.7M and *ad libitum* intake. However, the values of non carcass parts where expressed in percentage of body weight from this study are similar to other reports of studies on Thai native cattle (Jaturasitha et al., 2009; Waritthitham et al., 2010). The internal organ excluding reticulum, small intestine and liver were (P>0.05) not affected by increasing energy intake. Liver was larger in cattle fed high energy intake and declined in cattle fed low energy intake. This result supports the work of Murphy and Loerch (1994), who found that when the intake level rose from 80% to 100% of *ad libitum*, liver weight also increased. While, Hick et al. (1990) and Rust et al. (1986) found that the reduction of liver weight was observed in restricted feeding of Holstein steers, This is similar to the report of Ferrell and Jenkins (1998) and Galvani et al. (2008), who found that the liver weight of beef cattle increased in changing nutrition plane from restricted to *ad libitum* intake. However, this aspect remains unclear and many researchers are required to demonstrate the relationship between liver size, feed intake and animal energy expenditures (Ferrell , 1988; Galvani et al., 2008; Mader et al., 2009).

Table 3.2.4 Carcass compositions of Thai native beef cattle fed diets containing various metabolizable energy intake

Item	Levels of energy feeding			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Non-carcass, % of body weight						
Blood	2.33	1.92	2.09	0.25	0.4931	0.3469
Head	6.8[a]	6.48[ab]	6.26[b]	0.13	0.0156	0.7040
Hide	8.98	8.2	8.33	0.58	0.4261	0.5036
Tail	0.52[a]	0.44[ab]	0.61[b]	0.02	0.0874	0.0907
Shank	2.88[a]	2.47[b]	2.26[c]	0.08	0.0006	0.2464
Gastrointestinal organ, % of body weight						
Reticulum	0.25[a]	0.23[ab]	0.15[b]	0.02	0.0056	0.3321
Rumen	1.41	1.5	1.44	0.08	0.7948	0.4191
Omasum	0.57	0.61	0.55	0.03	0.7810	0.2900
Abomasum	0.3	0.32	0.29	0.02	0.9314	0.4348
SI	1.41[b]	1.66[a]	1.51[ab]	0.06	0.9777	0.0017
LI	0.58	0.56	0.53	0.09	0.7595	0.9491
Caecum	0.1	0.12	0.09	0.01	0.424	0.1781
Rectum	0.25	0.23	0.15	0.02	0.0056	0.3321
Esophagus	0.15	0.16	0.11	0.01	0.0687	0.1461
Visceral organ, % of body weight						
Heart	0.47	0.49	0.49	0.04	0.6729	0.9018
Kidney	0.2	0.2	0.2	0.007	0.6854	0.9161
Lung	0.73	0.75	0.67	0.04	0.3930	0.4648
Trachea	0.17	0.18	0.18	0.02	0.6033	0.8648
Liver	1.05[b]	1.35[a]	1.31[ab]	0.002	0.0574	0.1859
Pancrease	0.1	0.13	0.11	0.009	0.3868	0.1029
Spleen	0.33	0.32	0.32	0.02	0.8843	0.8450
Gall bladder	0.02	0.03	0.02	0.001	0.5624	0.0505
Uterine bladder	0.08	0.08	0.05	0.01	0.2690	0.4947
Reproductive system	0.38	0.38	0.4	0.07	0.8540	0.9507

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

2) Carcass quantity

A positive linear effect *($P<0.05$)* was found for live weight at slaughter (shrunk weight), warm carcass weight and chill carcass weight while the energy intake increased. The carcass trait as dressing percentage, rib eye area, %KPH and yield grade were not significantly ($P>0.05$) affected by the difference of energy intake. The data of carcass trait are shown in Table 3.2.5. The dressing percentage from this study ranged from 51.67%-53.18%, which is lower than the dressing percentage of Thai native purebred from reported by Jaturasitha et al. (2009) (54.5%-55.1%) and Thai native crossbred from the report of Waritthitham et al. (2010) (56.2%-58.1%).

Furthermore, the data from this study implies that the dressing percentage of Thai native cattle is lower than British cattle from the report of Murphy and Loerch (1994) (60.3%-61.4%) and bison from the work of Koch et al. (1995) (60.7%-64.3%), but which was higher than Arsi cattle fed under restricted condition from the report of Tolla et al. (2003)(48.4%-51.5%). However, Waritthitham et al. (2010) suggested that the low dressing percentage may be partly due to insufficient nutrient supply and incomplete fattening of cattle, while Kaene and Allen (1998) revealed that increase of carcass weight was related to live body weight and carcass dimensions during growth, but that there is no effect on the dressing percentage. Rib eye area and rib fat were similar to other researchers (Ferrell and Crouse, 1978; Jaturasitha et al., 1989; McPhee et al., 2006). Koger et al. (1973) and Ferrell and Jenkins (1998) indicated that rib eye area was related to the breed, feeding pattern, percentage of carcass and percentage of cutability. The muscle of cattle fed 1.7M and *ad libitum* intake are higher *($P<0.05$)* than that of cattle fed 1.3M. The bone weight was not different ($P>0.05$) across all groups. The muscle per bone ration linearly increased *($P<0.05$)* by increasing energy intake. These results indicate that increasing energy intake increases the proportion of muscle in the carcass, which is close to the report from Kelly et al. (1968) and Sugimoto et al. (2004), who found that the ratio of muscle per bone increased with rising plane of nutrition. However, Chauychuwong et al. (1997) and Sirisom and Rattanajamroon (2003) reported that higher lean percentage and less subcutaneous fat were found in the carcass of *Bos taurus* and crossbred cattle compared to *Bos indicus* cattle.

Table 3.2.5 Carcass quality of Thai native beef cattle fed diets containing various metabolizable energy intake

Item	Levels of energy feeding			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Initial weight, kg	92.92	95.17	94.75	2.51	0.6170	0.674
Slaughter weight, kg	131.08^{b}	147.83^{ab}	163.60^{a}	6.81	0.0218	0.7821
Warm carcass weight, kg	69.38^{b}	79.08^{ab}	88.60^{a}	3.46	0.0109	0.7688
Chill carcass weight, kg	68.00^{b}	76.47^{ab}	87.04^{a}	3.54	0.0137	0.9528
% chilling loss	2.15	3.31	1.81	0.44	0.8803	0.075
Dressing percentage, %	51.89	51.67	53.18	1.07	0.6345	0.6562
Rib eye area, cm^2	55.96	66.38	62.87	0.83	0.6345	0.1934
Rib fat , mm	1.83	2.66	2.59	0.05	0.2918	0.3931
KPH, %	3.49	4.05	4.22	0.71	0.2986	0.6762
Yield grade, %	2.21	2.51	2.17	0.18	0.1147	0.1882
Muscle, kg	55.47^{b}	65.23^{a}	70.95^{a}	2.77	0.0086	0.6541
Bone, kg	13.84	14.68	15.61	0.53	0.1753	0.7152
Muscle, % of carcass	79.91^{b}	82.55^{a}	79.88^{b}	0.58	0.0086	0.4531
Bone , % of carcass	20.06^{a}	18.61^{ab}	17.93^{b}	0.49	0.0132	0.6523
Muscle / bone ratio	4.02^{b}	4.47^{a}	4.49^{a}	0.13	0.0253	0.3164
Daily carcass gain, kg/d	0.51^{b}	0.58^{ab}	0.65^{a}	0.03	0.0109	0.7689
Daily lean gain, kg/d	0.41^{b}	0.48^{a}	0.521^{a}	0.02	0.0096	0.4312

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

The standard beef cutability and Thai style cutting of Thai native beef cattle from this study are shown in Table 3.2.6. Flank cuts of cattle fed 1.7 M and *ad libitum* intake was are a higher percentage of the carcass than that cattle fed 1.3 M. The other parts were not (*P*>0.05) influenced by energy increase. This result is supported by Sethakul et al. (2005), who found that the increasing nutrient intake affected carcass weight, but the percentage of primal cuts and hindquarter did not change. The range of primal cuts weight from this current study is similar to the result from other reports, studies on the beef cutability of Thai native cattle (Jaturasitha et al., 2009; Waritthitham et al., 2010). Moreover, there are no (*P*>0.05) differences on beef cuts in Thai style cutting. The higher bone expressed as percentage of carcass in cattle fed 1.3M shows that a change in muscle and carcass composition may be partially responsible for improvements in feed efficiency when intake is restricted (Murphy and Loerch, 1994). This comment is support the reported by Waritthitham et al. (2010), who proposed as a general ideal, that superior carcass has a high proportion of muscle, a low proportion of bone. Nevertheless, the increase of beef cuts especially the muscle in hindquarter is a benefit for producers because it is the main determinant of yield and commercial value (Kampster, 1992; Sethakul et al., 2007).

Table 3.2.6 Wholesale cuts and retail cut from Thai style cutting of Thai native beef cattle fed diets containing various metabolizable energy intake

Item	Levels of energy feeding			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Wholesales cuts, % of carcass						
Chuck	24.94	24.35	26.45	0.7500	0.2005	0.1558
Brisket	12.88	13.19	11.81	0.8600	0.4197	0.4467
Rib	9.23	9.45	9.83	0.5900	0.1809	0.4442
Plate	4.37	4.91	5.09	0.2900	0.0993	0.5987
Flank	1.89[b]	2.6[ab]	3.07[a]	0.3600	0.0508	0.6920
Shortloin	8.36	8.11	7.91	0.4200	0.5927	0.8900
Sirloin	11.75	10.9	10.83	0.3000	0.1310	0.1590
Round	26.10	26.05	24.86	0.5900	0.1809	0.4442
Thai style cutting, % of carcass						
Longissimus dorsi	5.89	6.81	6.3	0.7400	0.7841	0.3631
Proas major	2.03	2.45	2.28	0.2100	0.7221	0.1567
Semimembranosus	20.18	19.63	18.84	1.4900	0.6403	0.9678
Grastocnemius	4.73	4.55	4.75	0.2300	0.9804	0.4999
Redmeat	30.69	30.08	32.04	2.4000	0.7838	0.6970
Tiger cry	4.53	5.06	5.27	0.3600	0.2316	0.5856
Flank+Plate	4.65	4.28	5.65	0.3900	0.2301	0.1364
Fat	4.54	5.04	5.65	1.1800	0.3156	0.8056
Bone	20.09[a]	18.61[ab]	17.93[b]	0.5600	0.0113	0.6290

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

3) Meat composition and consumer acceptable

The meat composition in beef cattle and consumer acceptability can be explained in Table 3.2.7 and Table 3.2.8, respectively. Differences in muscle types influence the meat acceptablility of consumer and the nutrient accumulated in meat. The energy intake and muscle types influence meat composition, but there was no interaction between two factors. The results from this study showed that the general red meat is lowest in protein content, but highest in fat, while, the nutrient retained in longissimus dorsi is not different from proas major and semimembranosus muscle. In the consumer acceptablility test, the longissimus dorsi and praos major muscle were largest ($P<0.05$) tender and more juicy muscle than semimemranosus and tiger cry muscle. In overall acceptablility there were no ($P>0.05$) differences between longissimus dorsi, praos major and semimemranosus, but all of the three groups were higher ($P<0.05$) in acceptibility than tiger cry muscle. The energy intake of the animal had no ($P>0.05$) influence on meat palatability. However, the age and breed of beef cattle are the main factors influencing tenderness and overall acceptablility. This could be due to the quantity, solubility and space organization of the collagen (Shackleford et al., 1994; Wulf et al., 1996). In several reports imply that breed and genetic differences affect beef tenderness and that genetics of beef is associated with variation in the rate and extent of muscle proteolysis of fresh beef (Ilian et al., 2001; Monson et al., 2005).

4) The fatty acid composition in muscle

The fatty acid composition of longissimus dorsi muscle and semimembranosus muscle were shown in Table 3.2.9. The muscle type, energy intake level and interaction between muscle type and energy intake had no influence on total fatty acid profile, but the muscle type affected the unsaturated fatty acid $C18:2_{c10t12}$ and $C18:2_{c10c12}$. The energy level did not influence most of the fatty acid profile excluding $C18:2_{c10c12}$. The result indicate that the fatty acid profile especially healthy fatty acid as conjugated linoleic fatty acid is not improved by increasing energy intake. Shellito and Maiorano (2002) studied the effect of grazing and feedlot fattening on fatty acid profile and found that there was no difference between grazing and fattening patterns. The conjugated linoleic fatty acid from this study, which was calculated in the unit of g/100 g of fat ranged from 0.235-0.304 g/100 g of fat. The results are lower than Charolais beef cattle from the report of Sarries et al. (2009)(0.34-0.93 g/100 g of fat) and crossbred steer from the report of French et al. (0.47-0.66 g/100 g of fat). However, the variation of fatty acid profile of beef is mostly diet dependent (Jaturasitha et al., 2009). The fatty acid profile, in particular conjugated linoleic fatty acid content of ruminant tissue has been studied to a much lesser extent. More fatty acid profile research is needed to improve meat quality in the future.

Table 3.2.7 Effect of dietary energy intake on meat chemical composition of Thai native beef cattle

	Muscle*					Energy level				*P-value*		
	SM	RM	LD	PM	GN	1.3M	1.7M	*ad libitum*	SEM	Muscle	Energy level	Muscle*energy level
DM	34.26^{a}	31.21^{c}	32.59^{b}	33.02^{b}	32.49^{b}	32.06^{b}	32.85^{a}	33.34^{a}	0.15	0.0001	0.0025	0.8452
CP	21.23^{ab}	20.31^{c}	21.44^{ab}	20.31^{a}	21.50^{ab}	21.65^{a}	20.90^{b}	20.64^{b}	0.14	0.0004	0.0191	0.9584
Ash	4.21^{a}	3.99^{a}	3.98^{a}	3.92^{a}	3.44^{b}	4.08^{a}	3.87^{ab}	3.75^{b}	0.07	0.0156	0.1423	0.7869
EE	6.42^{b}	7.99^{a}	6.90^{ab}	6.53^{b}	5.18^{c}	5.88^{b}	6.66^{ab}	6.96^{a}	0.21	0.0001	0.0943	0.7724

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

* Type of muscle, LD = longissimus dorsi, PM = praos major, SM = semimembranosus RM = general red meat and GN = gastrocnemius

Table 3.2.8 Meat acceptable of Thai native beef assessed by consumer test

	Muscle				Energy level				*P-value*		
	LD	PM	SM	TG	1.3M	1.7M	*ad libitum*	SEM	Muscle	Energy level	Muscle*energy level
Tenderness	1.82^{b}	1.76^{b}	2.01^{a}	1.98^{a}	1.98^{a}	1.86^{b}	1.83^{b}	0.0258	0.0007	0.028	0.3029
Juiciness	1.98^{b}	2.04^{b}	2.02^{b}	2.24^{a}	2.05	2.04	2.12	0.0160	0.0012	0.4126	0.0066
Flavor	1.94^{b}	1.94^{b}	2.06^{ab}	2.17^{a}	2.03	2.01	2.04	0.0240	0.0013	0.9356	0.1274
Overall	1.91^{b}	1.87^{b}	2.00^{ab}	2.08^{a}	1.94	1.99	1.96	0.0235	0.0109	0.7228	0.2389

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

* Type of muscle, LD = longissimus dorsi, PM = praos major, SM = semimembranosus and TG = tiger cry

Score 1 to 4, where 1 = extrenly tender, juicy,intense and acceptable , 4 = extreamly tough, dry, bland and unacceptable

Table 3.2.9 Effect of dietary energy intake and muscle type on fatty acid composition in meat of Thai native beef cattle

	Muscle*		Energy level			SEM	*P-value*		
	LD	SM	1.3M	1.7M	*ad libitum*		Muscle	Energy level	Muscle*energy level
Fatty acid profile, % of total fatty acid									
C12:0	0.5971	0.5482	0.6767	0.5167	0.5150	0.0524	0.6488	0.3553	0.5632
C14:0	6.2176	5.4594	5.8383	5.8933	5.7730	0.2157	0.1007	0.9754	0.2281
C14:1	0.8200	0.7088	0.7567	0.7650	0.7730	0.0431	0.1879	0.9885	0.4514
C16:0	28.6460	27.9760	27.9550	29.0820	27.8140	0.5895	0.5800	0.6295	0.0863
C16:1	0.6988	0.8394	0.7192	0.7908	0.8030	0.0679	0.2562	0.8613	0.1334
C18:0	19.7260	20.1180	19.4980	21.3580	18.7090	0.8742	0.8846	0.4591	0.6392
C18:1	35.9330	34.0930	35.0360	35.3220	38.2150	1.2743	0.5545	0.1882	0.1054
C18:2	0.0718	0.0994	0.0958	0.0866	0.0720	0.0078	0.0963	0.4755	0.7470
C18:3	0.1176	0.2459	0.2633	0.1508	0.1210	0.0355	0.1010	0.2408	0.4599
Other FA	3.5506^{b}	4.9253^{a}	4.4080	4.5333	3.6400	0.3136	0.0554	0.4748	0.1171
CLA and CLA derivative, % of total fatty acid									
C18:2t8c10	0.0081	0.0070	0.0073	0.0108	0.0040	0.0025	0.8964	0.5506	0.5542
C18:2t9c11	0.0181	0.0000	0.0000	0.0116	0.0150	0.0061	0.1653	0.5991	0.5991
C18:2t10c12	0.0056	0.0193	0.0000	0.0000	0.0000	0.0030	0.0505	0.5046	0.1768
C18:2c9t11	2.7869	4.0588	3.7727	3.6000	2.8890	0.2862	0.0516	0.5190	0.7846
C18:2c10t12	0.1825^{b}	0.2564^{a}	0.2190	0.2416	0.1970	0.0146	0.0230	0.4774	0.5530
C18:2c8c10	0.0000	0.0035	0.0018	0.0016	0.0020	0.0009	0.0704	0.9868	0.9868
C18:2c9c11	0.0037	0.0000	0.0018	0.0033	0.0000	0.0011	0.1151	0.4685	0.4685
C18:2c10c12	0.0931^{b}	0.1523^{a}	0.0681^{b}	0.1575^{a}	0.144^{a}	0.0130	0.0281	0.0205	0.3161
C18:2c11c13	0.0537	0.0300	0.0718	0.0033	0.0540	0.0222	0.5279	0.4382	0.4929
C18:2t11t13	0.1912^{b}	0.4058^{a}	0.2663^{ab}	0.4142^{a}	0.2060^{b}	0.0372	0.0093	0.0769	0.6905
Other CLA	0.1769	0.0547	0.2645	0.0433	0.0300	0.0713	0.3648	0.2948	0.3389
Total CLA	3.5913	4.9871	4.7855	4.5033	3.5560	0.3445	0.0773	0.3939	0.2827

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

* Type of muscle, LD = longissimus dorsi, and SM = semimembranosus

3.2.4 Conclusion

A positive linear *($P<0.05$)* effect was found for feed intake, energy loss in feces, energy retention and heat production as the energy intake increased, but the energy loss in urine was not *($P<0.05$)* influenced by increasing energy intake. Energy gain as protein and fat deposition were influence *($P<0.05$)* by increasing energy intake. The levels of energy intake did not *($P<0.05$)* affect carcass quantity and carcass weight excluding intestinal organ such as reticulum, small intestine and liver. The energy level did not influence most of the fatty acid profile excluding C18:2c10c12. The level of energy intake and type of muscle affected *($P<0.05$)* the chemical composition of meat, but there was no interaction *($P<0.05$)* between energy intake and muscle type. Consumer acceptability depended *($P<0.05$)* on type of muscle, while the energy intake affected *($P<0.05$)* the tenderness. No interaction *($P<0.05$)* between energy intake and type of muscle on beef palatability. In the fatty acid profile, the muscle type, level of energy intake and interaction between muscle type and energy intake did not *($P>0.05$)* influence the fatty acid profile in cattle fed all treatments, but the muscle type affected *($P<0.05$)* the derivative of conjugated linoleic fatty acid as C18:2c10t12 and C18:2c10c12. The total conjugated linoleic fatty acid was not *($P>0.05$)* different in all energy intakes and all muscle types. No interaction between muscle type and energy intake on total conjugated linoleic fatty acid.

From this study, the metabolizable energy requirement for maintenance and net energy requirement for maintenance of Thai native beef cattle were 485.47 KJ/kgEBW$^{0.75}$/d and 332.05 KJ/kgEBW$^{0.75}$/d, respectively. The efficiency of metabolizable energy for maintenance and for growth from this current study can be estimated and which were 0.68 and 0.41, respectively.

3.3 Part 3: GROWTH PERFORMANCE, NUTRIENTS DIGESTIBILITY, RUMEN FERMENTATION AND BLOOD METABOLITES IN YEARLING THAI NATIVE CATTLE FED VARIOUS METABOLIZABLE ENERGY INTAKE

3.3.1 Introduction

Cattle are an ideal animal in meat production for beef industry of Thailand. According to the Department of Livestock Development estimate, there are 8,595,428 heads of beef cattle and approximately 63.31% are Thai native breed. They are smaller mature body size and grow at a slower rate compared to the breeds found in temperate countries. However, they have the ability to survive under poor conditions and are well adapted to low quality diets of sub-humid tropical zone. Most Thai native beef cattle were derived from small-holder farmers, who need to improve beef production efficiency and they require information on appropriate feeding programs for sustainable production development. Keys to the successful boosting of farm benefits and decreasing feed costs are based on feeding management. Energy is the main constraint of feed cost for the beef industry, but there is still very limited data on energy requirement and energetic efficiency. AFRC (1993) recommended that energy supply is normally the first limiting factor in microbial protein synthesis, because microbial growth is dependent on the supply of fermentable carbohydrate (Nocek and Russell, 1988). Schroeder and Titgemeyer (2008) suggested that energy supplementation can improve the efficiency of amino acid utilization and body protein gain increased from 52 to 60% when calves received higher energy intake. This data was used to the support work of Sejrsen and Purup (1997), who found that high-energy diets allowed rapid body weight gain and excess fattening in heifers. Furthermore, this result was similar to the report of Bartlett et al. (2006), who found that at higher levels of energy intake, the potential of protein deposition was greater and increased the protein gain of the body. Nevertheless, in most circumstances, when dry matter and energy intake are restricted at the same time, average daily gain decreased and carcass weight was reduced (Clark et al., 2007; Rossi et al., 2001). In Thailand, Sukho (2008) found that nutrient digestibility and energy utilization of Thai native cattle and Brahman cattle fed under the same conditions were not different. Moreover, Kaewpila (2010) reported that nutrients digestibility and ammonia nitrogen concentration of Thai native cattle were not influenced by increasing metabolizable energy intake. However, the growth performance, digestibility, blood metabolites and rumen fluid parameters data on Thai native cattle offered varying energy intake are not yet clearly defined. Therefore, the purpose of this study was to investigate the effects of energy intake on growth performance, digestibility, blood metabolites and rumen fermentation in Thai native cattle.

3.3.2 Materials and Methods

3.3.2.1 Animals and experimental design

This study was carried out from April 2007 to August 2007. Animals were kept at Khon Kaen University's farm of the Faculty of Agricuture, Khon Kaen University, Thailand. Eighteen growing male Thai native beef cattle, with average initial body weight of 94.30 ± 16.5 kg and 13 months of age were used in this experiment. Animals were kept in individual stalls with free access to drinking water and mineral block. All animals were treated to remove parasites by using Ivermectin (IVOMEC-F, Merck, Rahway, USA) intramuscular injected at 1 ml per 50 kg of body weight and they were vaccinated against foot and mount disease prior to the start of the experiment. Beef cattle were blocked (by weight) and randomly allocated to one of three dietary treatments in a randomized complete block design (RCBD) with six animals in each group. Treatments were levels of metabolizable energy intake as follows; T1 = 1.3 of maintenance (1.3M), T2 = 1.7 of maintenance (1.7M)and T3 = *ad libitum*. (assuming M = 450 KJ/kgBW$^{0.75}$/d, according to Chaokaur et al. (2007)).

Animals were housed in the individual pens and allowed for adaptation period of 2 weeks prior to 136 days of data collection period. In the adaptation period, the cattle were fed *ad libitum* of roughage and 1.5%BW of concentrate. The animals were weighed at the beginning and the end of the adaptation period when the feed intake was constant. In digestion trial period, animals were moved to metabolic cage and adapted to handling on the cage for 7 days before collection period started.

3.3.2.2 Feed preparation and management

Daily total mixed ration of ruzi hay and concentrate was offered throughout the course of feeding trial. The concentrate portion of diet (dry matter basis) consisted of palm kernel meal (10%), coconut meal (4%), cassava chip (32%), ricebran (22.5%), urea (1%) and mineral (0.5%). The composition and chemical analysis of the diets are presented in Table 3.3.1. Animals were fed twice daily at 08.00 and 16.00 h.

Animals were weighed every 2 weeks at the same time of the day (06.00 h) before being offered feed. The weight of each animal was used as the basis for calculating the daily feed allocation for the next 14 days.

Table 3.3.1 Ingredients and chemical composition of feeds

Items	DM basis (%)
Ingredients	
Ruzi grass hay	30.0
Cassava chip	32.0
Rice bran	22.5
Coconut meal	4.0
Palm kernel cake	10.0
Urea	1.0
Mix mineral	0.5
Chemical composition , %	
DM	93.80
CP	10.03
OM	94.68
EE	4.70
NDF	37.13
ADF	23.98
Energy content, MJ/kg DM	
GE	18.02
DE	11.54
ME	10.43

3.3.2.3 Data collection and chemical analysis

1) Data collection and sampling method

Daily feed intake was recorded and orts collected from individual animals in the morning of the next day. Feed consumption was measured daily based on the offered and refused quantities. Animals were weighed and measured for body height, length and heart girth every 2 weeks at the same time of the day (06.00 h) before offering feed. The values for average daily gain and average body size gain were calculated. The new weight of each animal was used as the basis for calculating the daily feed allocation for the following 14 days. Samples of feed and feed refusal were collected once every 2 weeks for chemical analysis. Feeds and orts were dried at 100 °C for dry matter calculation and dried at 60 °C, ground to pass a 1-mm screen (Retsch, Model: SM 2000/695 Upm. GmbH&Co.kG Rheinische strabe 36, 42781 Haan. Germany), and proportionally subsampled to a composite sample. The composite sample (feeds and orts) were stored until chemical analysis.

In the digestion trial period, total feces and urine quantities were recorded. Feces were sampled ~ 10% of total output and collected in plastic bag before being stored at -18 °c. Urine was collected in plastic buckets containing 20% H_2S0_4 to maintain pH below 3.0 and a 500 ml sample was taken daily. At the end of the period, samples were thawed, mixed thoroughly, sub-sampled and oven-dried (feces) at 60 °c for at least 72 h. Feces was ground and passed through a 1-mm screen, and stored for chemical analysis. The blood sample of each animal was collected at the end of the experimental period before feeding and 3 h, 6 h, 9 h post-feeding. All blood samples were collected via the jugular vein, placed in ice and transported to the laboratory prior to centrifugation. Serum was stored frozen (-18 °c) for further analysis. Approximately 100 ml of rumen fluid from each animal was collected by aspiration using stomach tube 0 h, 3 h, 6 h and 9 h post-feeding at the end of the experimental period. All samples of rumen fluid were filtered through two layers of cheesecloth. The pH of rumen fluid was measured using an electric pH meter (Orion Research Model SA 230). Samples were subsequently stored at -18 °c in plastic bottles containing 6N HCl to prevent further fermentation.

2) Chemical analysis

Feed, orts and feces were analyzed for dry matter, crude protein, ether extract and ash according to AOAC (1990), neutral detergent fiber and acid detergent fiber according to Van Soest (1970). Compounds of urine were taken for N determination with Kjeldahl N procedure and gross energy by auto-calculating bomb calorimeter (SHIMADZU CA-4PJ, SHIMADZU COPORATION, JAPAN). The frozen rumen fluid samples were defrosted at room temperature and centrifuged for 15 min at 3500 rpm. The supernatant was analyzed for ammonia nitrogen by steam distillation according to Bromner and Keeney (1965) Serum was defrosted and analyzed for blood urea nitrogen and blood glucose according to Bodine and Purvis (2003).

3.3.2.4 Calculation and statistical analysis

Energy content of feed was measured by using data from the digestion trial. Gross energy intake was calculated from gross energy content in feed multiplied by average daily feed intake. Digestible energy intake of each animal was determined as the difference between gross energy intake and output of fecal energy (FE). Metabolizable energy intake (MEI) was calculated as gross energy intake minus feces energy (FE) and urine energy (UE), multiplied by 0.93 to correct for fermentation losses according to ARC (1980) and Liang and Young (1995). Average daily gain and average body size gain were estimated from a linear regression;

$$Y = a + b\,(X)$$

Y values represents weights, X values represents number of days in the experiment and the slope (b) represent the average daily gain for 136 days period following the beginning of treatment period according to Liang and Young (1995).

All data were analyzed with general linear models procedure and treatment means were compared by Duncan's new multiple range test (SAS, 1996) according to a randomized complete block design as in the following model;

$$Y_{ij} = \mu + \rho_i + \tau_j + \varepsilon_{ij} \,;$$

where Y_{ij} is the observed value for a dependent variable on ij, with μ is overall mean, ρ is the effect of block i, τ is the effect of dietary treatment j and ε is the random experimental error.

3.3.3 Results and Discussion

3.3.3.1 Feed intake and energy intake

Feed intake and energy intake are presented in Table 3.3.2. A positive linear effect *($P<0.01$)* was found for feed intake as the energy intake increased. The highest feed intake was obtained in cattle fed *ad libitum* (2.84 kgDM/d) and lowest intake was found in cattle fed 1.3 M (1.97 kgDM/d). There were linear effects *($P<0.01$)* for gross energy intake and digestible energy intake with increasing dry matter intake.

Metabolizable energy intake increased linearly *(P<0.01)* between 1.3 M, 1.7 M and *ad libitum* group, as a result of higher dry matter intakes. Metabolizable energy intake from this current study ranged from 590.83 to 768.86 KJ/kgBW$^{0.75}$/d. Energy loss in feces was lowest in 1.1 M and highest in *ad libitum* group, but there was no difference *(P>0.05)* between 1.7 M and *ad libitum* group. Energy loss in urine of all treatments was not influenced *(P>0.05)* by levels of metabolizable energy intakes. This study is similar to the report of Freetly et al. (2008), who found that energy losses in feces and urine followed the same patterns of increase as energy intake of beef cows. Kirkpatrick et al. (1997) and Kurihara et al. (1999) found that energy loss in feces and urine in cattle offered high energy intake seemed to be greater than cattle fed low energy intake.

Table 3.3.2 Effect of metabolizable energy intake (1.3M, 1.7M and *ad libitum*) on energy partition and energetic efficiency of Thai native beef cattle

	Level of metabolizable energy intake				Polynomial contrast	
Item	1.3 M	1.7 M	*ad libitum*	SEM	*L*	*Q*
No.of animal	6	6	6			
Initial weight, kg	92.92	95.17	94.75	2.51	0.617	0.674
Final weight, kg	134.45^{b}	151.75^{ab}	164.72^{a}	6.21	0.006	0.782
Average body weight, kg	113.68^{b}	123.46^{ab}	129.73^{a}	9.06	0.022	0.734
Metabolic body weight, kg	34.75^{b}	36.96^{ab}	38.31^{a}	1.22	0.026	0.728
Feed intake (kgDM/d) *	1.97^{b}	2.54^{a}	2.84^{a}	0.11	0.003	0.37
Energy intake **						
GE intake, KJ/kgBW$^{0.75}$/d	1063.91^{b}	1202.72^{a}	1279.63^{a}	29.17	0.002	0.37
DE intake, KJ/kgBW$^{0.75}$/d	675.41^{b}	795.12^{a}	829.61^{a}	26.02	0.008	0.29
ME intake, KJ/kgBW$^{0.75}$/d	590.83^{c}	713.53^{b}	775.16^{a}	17.15	0.001	0.13
Energy loss **						
Feces excretion, KJ/kgBW$^{0.75}$/d	388.50^{b}	407.60^{ab}	450.03^{a}	17.83	0.05	0.61
Urine excretion, KJ/kgBW$^{0.75}$/d	21.23	23.49	24.41	1.01	0.09	0.59
FE/GE, %	36.57	33.94	35.19	1.57	0.53	0.29
UE/GE, %	2.27	1.96	1.92	0.13	0.06	0.42
Energetic efficiency						
DE/GE	0.63	0.65	0.64	0.01	0.022	0.783
ME/GE	0.57	0.60	0.58	0.01	0.021	0.827
ME/DE	0.89	0.90	0.90	0.001	0.154	0.401

* calculated from feeding trial (136 days) and ** calculated from digestion trial (21 days)

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

3.3.3.2 Nutrient intake and nutrient digestibility

Nutrient intake and digestion data are presented in Table 3.3.3 Organic matter intake, neutral detergent fiber intake and acid detergent fiber intake were not significantly *(P*>0.05*)* affected by the difference of metabolizable energy intake, but the organic matter intake tended to response linearly to increasing energy intake *(P<0.06)*. Crude protein and ether extract intake, where expressed in kg per day increased linearly *(P*<0.05*)* as the energy intake increased.

Apparent digestibility of all nutrients were not *(P*>0.05*)* affected by the difference of metabolizable energy intake. This finding demonstrates that increased energy intake can not improve diet digestibility. This result is in good agreement with Reed et al. (2007), who found that organic matter, neutral detergent fiber and acid detergent fiber digestibility of total tract were similar between steers fed high protein intake and low protein intake. Similarly, Walsh et al. (2008) also reported that when metabolizable energy intake in beef cattle increased from 108.3 to 121.2 MJ/h/d, the digestibility of organic matter, crude protein and neutral detergent fiber were not affected. Furthermore, this study supports the report of Shellito et al. (2006), who found that total tract digestion of dry matter, organic matter and nitrogen cannot be improved by increasing intake level and microbial efficiency in the rumen was not different in restricted-fed steers and *ad libitum*-fed steers.

Table 3.3.3 Effect of metabolizable energy intake (1.3M, 1.7M and *ad libitum*) on nutrient intake and digestibility of Thai native beef cattle

Item	Level of metabolizable energy intake			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Nutrients intake, kg/d						
OM	1.99	2.29	2.37	0.13	0.06	0.51
CP	0.21[b]	0.25[a]	0.26[a]	0.01	0.02	0.26
EE	0.10[b]	0.12[a]	0.14[a]	0.006	0.02	0.47
NDF	0.76	0.85	0.89	0.05	0.08	0.72
ADF	0.48	0.52	0.52	0.04	0.60	0.66
Nutrients digestibility, %						
DM	70.63	73.52	70.82	2.17	0.95	0.31
OM	71.50	72.58	67.34	2.21	0.20	0.26
CP	62.66	65.44	58.61	3.10	0.36	0.22
EE	80.56	80.17	80.09	2.04	0.87	0.94
NDF	58.31	58.69	51.54	3.25	0.16	0.35
ADF	49.03	50.07	39.76	3.87	0.11	0.24

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

However, this current study is the converse of the work of Browne et al. (2005) and Pereira et al. (2007), who found that increasing digestible energy intake of steer from 100 to 126 MJ/h/d, can improve organic matter and crude protein digestibility, but decreased neutral detergent fiber and acid detergent fiber digestibility. Compared with other reports from Thailand, this study is similar to that reported by Tangjitwattanachai and Sommart (unpublished data), that organic matter and crude protein digestibility in Thai native cattle were not influenced by level of metabolizable energy intake. Moreover, this finding is close to the report of Yuangklang et al. (2009), that the increased feeding level and protein intake cannot increase diet digestibility in Brahman cattle.

This study indicates that increased feeding and energy level intake cannot improve nutrients digestibility. However, it is unclear if changes in apparent digestibility are accompanied by changes in metabolizable energy intake or in efficiency of metabolizable energy use by the animal (Shellito et al., 2006; Clark et al., 2007).

3.3.3.3 Growth performance

The growth performances are shown in Table 4. The positive effect of metabolizable energy intake on average daily gain and average body dimension (height, length and heart girth) resulted in a linear relationship when metabolizable energy intake increasing from 590.83 to 768.86 KJ/kgBW$^{0.75}$/d. The highest average daily gain from this study was 521.20 g/d or 13.48 g/kgBW $^{0.75}$/d in cattle fed *ad libitum*.

The results from this study are in good agreement with Foldager and Krohn (1994) and Bar-Peled et al. (1997), who demonstrated that a high feeding and energy level can increase average daily gain of steers and heifers. Similarly, Sugimoto et al. (2004) reported that increased total digestible nutrient intake resulted in increased average daily gain and withers height gain in Japanese black cattle steers. The result from this current study is similar to that reported by Kirkland and Patterson (2006), that live-weight gain increased with increasing energy intake and that dry matter intake per live weight gain in steers decreased with increasing energy intake. Manninen et al. (2010) found that the *ad libitum* feeding generally increased daily weight gain, carcass fat score and improved the growth rate when compare with restricted feeding.

Table 3.3.4 Effect of metabolizable energy intake (1.3M, 1.7M and *ad libitum*) on average daily gain and average body size gain of Thai native beef cattle

Item	Level of metabolizable energy intake			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Body weight						
average body weight, kg	113.68[b]	123.46[ab]	129.73[a]	9.06	0.022	0.734
metabolic body weight, kg	34.75[b]	36.96[ab]	38.31[a]	1.22	0.026	0.728
average Daily Gain, g/d	307.52[c]	416.27[b]	521.20[a]	33.18	0.001	0.96
average Daily Gain, g/kgBW$^{0.75}$/d	8.83[c]	11.26[b]	13.48[a]	0.64	0.005	0.89
Height						
initial height, cm	89.33	89.83	89.83	1.34	0.79	0.88
final height, cm	99.25	99.25	101.67	1.47	0.27	0.52
average height gain, cm/d	0.07[b]	0.07[b]	0.09[a]	0.01	0.007	0.83
Length						
initial length, cm	72.00	71.33	70.50	1.48	0.49	0.96
final length, cm	82.08	84.50	87.50	1.64	0.04	0.88
average length gain, cm/d	0.07[b]	0.10[ab]	0.13[a]	0.01	0.007	0.84
Heart girth						
initial hearth girth, cm	108.33	110.33	110.33	1.40	0.33	0.57
final hearth girth, cm	123.33[b]	130.33[a]	132.00[a]	1.70	0.005	0.23
average hearth girth gain, cm/d	0.11[b]	0.15[a]	0.16[a]	0.01	0.007	0.35

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

The average daily gain of Thai native cattle from this study ranged from 307.52 to 521.20 g/d, which is close to the average daily gain of heifer calves fed moderate protein and energy intake reported by Brown et al. (2005) (379-668 g/d), Brahman and Boran beef cattle under restrict-fed (~ 585 KJ/kgBW$^{0.75}$/d of metabolizable energy intake) reported by Ferrell and Jenkins (1998) (300-330 g/d) and crossbred yellow cattle fed on low to high energy feeding (25-32 MJ/h/d of metabolizable energy intake) reported by Thang et al. (2010) (344-577 g/d). Titgemeyer et al. (2004) reported that increasing protein level did not improve nutrient utilization and growth rate when energy intake was limiting and that phase of growth depends on the level of energy supply (Iason and Mantecon, 1993; Chowdhury and Ørskov, 1997). When this study is compared with other research in Thailand, average daily gain from this current study is similar to Thai native cattle reported by Chantiratikul and Chumpawadee (2009) (190-410 g/d), but is lower than Brahman cattle from the report of Chaokaur et al. (2009) (237-946 g/d). Recent work by Schroeder et al. (2007) demonstrated that magnitude of the effect of energy supplementation on the efficiency of amino acid deposit protein depended on which amino acid limits the response to energy. These findings indicate that increase in energy intake can improve animal performance, as many other researchers have noted (Horn and McCollum, 1987; Bowman and Sanson, 1996; Caton and Dhuyvetter, 1997).

3.3.3.4 Ruminal pH, ammonia nitrogen, volatile fatty acid concentration and blood metabolites

Ruminal pH and ammonia nitrogen concentration are shown in Table 5. In this study, there was no effect *(P>*0.05*)* from increasing metabolizable energy intake. The ruminal pH of cattle fed all diets maintained the normal range for microbial activities in the rumen, which would be seriously inhibited if ruminal pH declined below 6.2 (Hoover and Stokers., 1991; Ørskov, 1998; Russel et al., 1992). However, the range from this research was 6.7- 7.2, which is above the critical pH for fiber microbe in rumen. The report of Murphy et al. (1994) indicated that ruminal pH of steers fed limited concentrate was not different than that of steer fed *ad libitum*. Moreover, restricted feeding intake did not negatively affect ruminal health or digestion of organic matter and nitrogen (Soto-Navarro et al., 2000). This finding indicates that an increase in energy intake has no influence on ruminal pH.

The ammonia nitrogen concentration showed no difference *(P>*0.05*)* across all treatments. These results are similar to the research of Hermesmeyer et al. (2002), that increased feeding intake was not reflected in increased ammonia nitrogen concentration in rumen. In the same way with the report of Elizalde et al. (1998), who indicated that ruminal pH and ammonia nitrogen concentration in the rumen is influenced more by time of the day than by treatments. By contrast, the work of Royes et al. (2009), found that when energy sources in diets were supplemented, ammonia nitrogen concentration in rumen declined. However, ruminal ammonia nitrogen levels from this research were above the recommended levels for maximum microbial growth (2 to 5 mg/dl) suggested by Satter and Slyter (1974) and which was higher than the values for microbial growth (10 mg/dl) in tropical conditions recommended by Leng (1990).

Table 3.3.5 Effect of metabolizable energy intake (1.3M, 1.7M and *ad libitum*) on ruminal pH, ammonia nitrogen, blood urea nitrogen and blood glucose concentration of Thai native beef cattle

Item	Level of metabolizable energy intake			SEM	Polynomial contrast	
	1.3 M	1.7 M	*ad libitum*		*L*	*Q*
Number animal, head	6	6	6			
pH	6.79	6.68	6.73	0.06	0.47	0.28
NH_3-N (mg/dl)	15.41	16.52	16.69	0.95	0.35	0.69
TVFA (mM)						
C_2	35.93	39.07	32.65	1.28	0.31	0.10
C_3	21.72	22.05	17.28	1.43	0.19	0.51
C_4	6.37	6.26	5.08	0.35	0.16	0.49
Total	60.69	68.35	56.04	2.27	0.42	0.06
Blood urea nitrogen (mg/dl)	7.30[ab]	6.01[b]	8.75[a]	0.66	0.13	0.03
Blood glucose (mg/dl)	79.50	81.14	85.50	3.06	0.18	0.72

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

The increasing metabolizable energy intake had no influence *($P>0.05$)* on volatile fatty acid concentration. The concentration of volatile fatty acid from this current study ranged from 56.04-68.35 mM. These results are in good agreement with the report of Elizalde et al. (1998), who revealed that volatile fatty acid concentration is not affected by supplements from various sources and levels of energy and which was also similar to work of Judkins et al. (1997) and Mazzenga et al. (2009), that the total volatile fatty acid concentration did not differ between cattle fed high energy density diets and low energy density diets. By contrast, the report of Clark et al. (2007), states that increasing energy and protein intake result in increased ruminal fermentation, as evidenced by the level of total volatile fatty acid production. However, the dietary protein had a major effect on volatile fatty acid concentration. If the animal obtained sufficient of protein, the volatile fatty acid concentration will increase and the ratio of C2 / C3 decrease. This finding may be supported by Hatfield et al. (1998), who found that the difference of volatile fatty acid concentration are attributable to the level of crude protein rather than level of dry matter intake.

Blood urea nitrogen and blood glucose are presented in Table 5. Blood urea nitrogen from this study ranged from 6.01-8.75 mg/dl. These results agree with the report of Walsh et al. (2009), who indicated that plasma urea nitrogen was not significantly different between cattle fed high-energy and low-energy intake. This contrasts with the research of Zanton and Heinrichs (2009) and Mapiye et al. (2009), who demonstrated that plasma urea nitrogen increased with increasing energy intake. In comparing with other researcher in Thailand, the values from this study are similar to other researchers (Yuangklang et al., 2009; Chantiratikul and Chumpawadee, 2009).

Blood glucose of cattle across all treatments were not different *(P>0.05)*. This current study indicates that blood glucose concentration is not influenced by increasing energy intake. This result is good agreement with Walsh et al. (2008) and Bermingham et al. (2008), who found that there was no relationship between increased feeding level and blood glucose in sheep. This contrasts with the report of Mapiye et al. (2009), who indicated that plasma glucose decreased with increasing energy intake. This study demonstrates that increased energy intake can not increase blood glucose concentration.

3.3.4 Conclusion

A positive linear effect was found for feed intake as the metabolizable energy intake increased. Metabolizable energy intake tended to increased linearly of all groups, as a result of higher dry matter intakes. All nutrient intake increased linearly with increasing metabolizable energy intake. All nutrients digestibility were not influenced by metabolizable energy intake. Average daily gain and average body size gain increased with increasing metabolizable energy intake. The average daily gain of Thai native cattle from this study ranged from 307.52 to 521.20 g/d. The ruminal pH, ammonia concentration and volatile fatty acid in rumen were not different across all treatments. Blood metabolites, such as urea nitrogen and glucose can not be improved by increasing energy intake.