CHAPTER V

A META-ANALYSIS: METABOLIZABLE ENERGY REQUIREMENT FOR MAINTENANCE OF THAI NATIVE CATTLE FED UNDER HUMID TROPICAL CONDITION IN THAILAND

5.1 Introduction

The establishment of feeding standard for ruminants has been urged for the sustainable development of beef industry in tropical developing countries (Kawashima et al., 2000). Ferrell and Jenkins (1998) and Ferrell et al. (2006) have suggested that *Bos indicus* cattle can be utilized low quality forage more efficiently than *Bos taurus* cattle in nutritionally restrictive environments and energetic efficiency for maintenance of *Bos indicus* was higher than *Bos taurus* cattle. These suggests were in good agreement with report of NRC (2000) who was indicated that *Bos indicus* breeds require about 10% less NE_m than beef breeds of *Bos taurus*. In Thailand, Tangjitwattanachai and Sommart (2009) analyzed data by using mixed linear model and reported that energetic efficiency for maintenance of *Bos indicus* was higher than that of *Bos taurus* about 9.38 % and energetic efficiency for growth of *Bos indicus* was higher than that of *Bos taurus* about 11.76%. Over the last 5 years, nutrient requirement studies in Thailand were investigating difference breeds (Thai native & Brahman). In the previously studies, Chaokaur et al. (2007) reported metabolizable energy requirement for maintenance of mature Brahman steers offered near maintenance level was 458 $KJ/kgBW^{0.75}/d$, which was higher than energy requirement for maintenance of Thai native cattle (245.18 $KJ/kgBW^{0.75}/d$) from report of Kawashima et al. (2000). However, the work of Kawashima et al. (2000) also does not support the energy recommendation for Thai native cattle by WTSR (2008), who was recently reported at 484 $KJ/kgBW^{0.75}/d$. Nevertheless, the variation of nutrients requirement of Thai native cattle in Thailand has not been elucidated, because of difference in sex, age, seasonal, temperature, level of nutrition, physiological state (NRC, 2000; Chizzotti et al., 2008) and measurement methods (Luo et al., 2004). Therefore, this research was aimed to determine metabolizable energy requirement for maintenance by meta-analysis, which was the new method, can be improved equations from statistical analysis (St- Pierre, 2001) and provide an overall summary, and its interpretation can provide direction for future experiments.

5.2 Materials and Methods

5.2 1 Description of database

5.2.1.1 Energy balance studies

The database included information from 4 indirect respiration calorimetry balance studies (62 observations from Kawashima et al., 2000; Moonmart, 2009; Nitipot et al., 2009 and Tangitwattanachai and Sommart, unpublished). All data were selected and identified by the sex of the animal (steer and bull). Animals from all studies were individually fed and the breed was coded as Thai native purebred. The dataset is shown in Table 5.1. The sets of experimental data arranged were subjected to regression analysis using the following model:

$$Y = a + bX$$

Where:

Y is the energy retention (KJ/kgBW$^{0.75}$/d) and X is the metabolizable energy intake (KJ/kgBW$^{0.75}$/d); the intercept, a is an estimate of the net energy for maintenance (NE_m). The metabolizable energy requirement for maintenance (ME_m) was calculated by assuming that the maintenance requirement is the value at which the energy retention is equal to zero (McDonald et al., 2002; Pond et al., 2005).

5.2.1.2 Long-term feeding trial studies

A database for the estimate of metabolizable energy requirement for maintenance was derived from 7 energy feeding trial studies (24 observations from Juthamas et al. unpublished data; Nitipot et al., 2009; Phaowphaisal and Wijitphan, 2006; Prajakboonjetsada et al., 2006; Sengsai et al., 2006; Tangitwattanachai and Sommart, unpublished data and Tamchan et al., 2007). Determination of the maintenance requirement of metabolizable energy used a long-term feeding trial (Taylor et al., 1986; Luo et al., 2004). The datasets are shown in Table 5.2. The sets of experimental data arranged were subjected to a regression analysis using the following model:

$$Y = a + bX$$

Where:

Y is the metabolizable energy intake (KJ/kgBW$^{0.75}$/d) and X is the average daily gain (g/kgBW$^{0.75}$/d). From the obtained equations, the metabolizable energy requirement for maintenance were determined by using calculations obtained by assuming that the maintenance requirement is the value at which ADG is equal to zero (Y-intercept; a) according to the method suggested by Luo et al. (2004).

5.2 2 Calculations and statistical methods

5.2.1.1 Energy balance studies

All data were constructed and analyzed to determine the metabolizable energy requirements for maintenance using a mixed linear model analysis (SAS, 1999) by regressing energy (ER) against metabolizable energy intake (MEI) according to St-Pierre (2001) and Patra (2009):

$$Y_{ij} = B_o+B_1X_{ij}+s_i^*+bi^*X_{ij}+e_{ij}$$

Where:

Y_{ij} is the expected outcome for energy retention; $B_o+B_1X_{ij}$ is the fixed effect part of model and $s_i^*+b_i^*X_{ij}+e_{ij}$ is the random effect part of model. The mixed linear model analysis was chosen because the data were gathered from multiple studies; therefore, it was necessary to consider analyzing not only fixed effects of the dependent variables, but also random effects (because the studies represented a random sample of a larger population of studies)(Ellis et al., 2007). The outlier of each variable dataset was identified and removed by using Univariate procedure, Stem and Leaf Plot and Box Plot (PROC UNIVARIATE; SAS, 1999). The performance of the derived prediction equation was tested by calculating the predicted values for each data using the prediction models and comparing these to the actual values. The degree of over-prediction or under-prediction was expressed as a mean proportion bias (%) which was calculated as the slope of the regression of actual on predicted values at zero intercept. A regression slope (at zero intercept) < 1.0 indicates under-prediction across the range of actual values according to Mandal et al. (2005). The accuracy of prediction was analyzed using the mean prediction error. Defined as (n-1 Σ $(A-P)^2$)/ actual mean where, A is the actual crude protein intake, P is the predicted value and n is the number of pairs of values being compared. A small mean prediction error indicates a good agreement prediction (Roseler et al., 1997). The model prediction was evaluated for accuracy by a paired t-test of actual and predicted values. A non-significant *($P>0.05$)* paired t-test between actual and predicted values indicated a good match between values calculated using the derived prediction model and actual values (Paul et al., 2003).

5.2.1.2 Long-term feeding trial studies

The dataset was analyzed using mixed linear model (SAS, 1999) by regressing the average daily gain ($g/kgBW^{0.75}/d$) against the metabolizable energy intake ($KJ/kgBW^{0.75}/d$) according to St-Pierre (2001) and Patra (2009):

$$Y_{ij} = B_o + B_1 X_{ij} + s_i^* + bi^* X_{ij} + e_{ij}$$

Where: Y_{ij} is the expected outcome for metabolizable energy intake, $B_o+B_1X_{ij}$ is the fixed effect part of model and $s_i^*+b_i^*X_{ij}+e_{ij}$ is the random effect part of the model. The outlier of each variable dataset was identified and removed by using Univariate procedure, Stem and Leaf Plot and Box Plot (PROC UNIVARIATE; SAS,1999). Performance of derived prediction equation was tested by calculating predicted values for each data using the prediction models and comparing these to the actual values. The degree of over-prediction or under-prediction was expressed as a mean proportion bias (%) which was calculated as the slope of the regression of actual on predicted values at zero intercept. A regression slope (at zero intercept) < 1.0 indicates under-prediction across the range of actual values according to Mandal et al. (2005). The accuracy of prediction was analyzed using the mean prediction error. Defined as (n-1 Σ $(A-P)^2$)/ actual mean where, A is actual crude protein intake, P is predicted value and n is number of pairs of values being compared. A small mean prediction error indicate good agreement prediction (Roseler et al., 1997). The model prediction was evaluated for accuracy by a paired t-test of actual and predicted values. A non-significant *($P>0.05$)* paired t-test between actual and predicted values indicated a good match between values calculated using the derived prediction model and actual values (Paul et al., 2003).

5.3 Results and Discussion

5.3.1 Energy requirement for maintenance and efficiency of energy utilization from energy balance studies

The metabolizable energy for maintenance was estimated by a linear regression analysis of metabolizable energy intake on energy retention. The equations are shown in Table 5.2. The regression equation developed in this study was highly significant ($P<0.01$) and R^2 values ranged from 0.45-0.71, which was highest in steer (0.71) and lowest in bull (0.45). RMSE of these results ranged from 14.49-91.52. The analysis of intercepts results in a common requirement for net energy for maintenance (NE_m) of 222.57 KJ/kgBW$^{0.75}$/d in steer, 232.09 KJ/kgBW$^{0.75}$/d in bull and 283.95 KJ/kgBW$^{0.75}$/d in pool data, which was lower than identical in *Bos taurus* cattle to the NE_m of 322.16 KJ/kgBW$^{0.75}$/d reported by Lofgreen and Garrette (1968), the values was commonly used by the NRC (1984, 2000) and lower than Nellore cattle from report of Tedeschi et al. (2002) (323 KJ/kgBW$^{0.75}$/d). These finding indicated that Thai native cattle require energy for basal metabolism lower than *Bos taurus* cattle. In other reports, Ferrell and Jenkins (1998) found that NE_m of *Bos indicus* cattle varied from 269.86 to 346.43 KJ/kgBW$^{0.75}$/d in Boran and Brahman cattle. However, the values in pool data of this report were close to the work of Chaokaur et al. (2008), who found that NE_m of Brahman cattle fed under tropical in Thailand was 289 KJ/kgBW$^{0.75}$/d and similar to Thai native cattle (281 KJ/kgBW$^{0.75}$/d) in Thailand from report of Nitipot et al. (2009). The results from this study suggested that the NE_m requirement was lower in *Bos indicus* than in *Bos taurus* and *Bos taurus* crossbreds.

A linear relationship of regressing MEI against ER was obtained, $ER = (-222.57)_{(79.94)} + 0.60_{(0.02)}\,MEI$ (n=34, R^2=0.70, RSD=14.48, $P<0.001$) for steer (equation 2), $ER = (-232.09)_{(67.80)} + 0.44_{(0.12)}\,MEI$ (n=25, R^2=0.45, RSD=8.54, $P<0.001$) for bull (equation 3) and $ER = (-283.95)_{(49.03)} + 0.63_{(0.03)}\,MEI$ (n=62, R^2=0.64, RSD=11.62, $P<0.001$) for pool data (equation 1) (see also in Table 5.2). From the equations 1-3 , it was found that the metabolizable energy requirement for maintenance was greater for bull than for steer (527.47 and 370.95 KJ/kgBW$^{0.75}$/d, respectively) but the efficiency of metabolizable energy for maintenance (k_m) value was 44% for bull and 60% for steer, which agrees with a report from Leal de Araujo (1998), who found that the k_m of bull was lower than steer but which is in contrast with work of Chizzotti et al. (2007), who found that k_m of Nellore steers were lower than bulls about 17% and lower than heifer about 23% Ferrell and Jenkins (1998) reported similar values of k_m ranging from 65-69% and greater k_g in crossbred *Bos indicus* X *Bos taurus* than in *Bos taurus* crossbred steers. The NRC (2000) assumes that steer have energy requirement for maintenance 15% less than bulls, but does not account for differences between steers and heifers. Likewise, the ME_m of pool data was 450.71 KJ/kgBW$^{0.75}$/d and k_m was 63%. This value was lower than suggested for Thai native cattle fed under tropical conditions in Thailand from WTSR (2008) (484 KJ/kgBW$^{0.75}$/d) and reported of Nitipot et al. (2009) (509 KJ/kgBW$^{0.75}$/d). In comparing with *Bos indicus* in other studies, it was found that these values were higher than the Malaysian native cattle from report of Laing and Young (1995) (335 KJ/kgBW$^{0.75}$/d), but lower than Brahman crossbred from a report of Ferrell and Jenkin (1998) (488 KJ/kgBW$^{0.75}$/d) and Brahman purebred fed under tropical conditions in Thailand from a report of Chaokaur et al. (2008) (497 KJ/kgBW$^{0.75}$/d). However, the result from this study was lower than beef cattle in temperate zone by recommendation of ARC (1980) (527 KJ/kgBW$^{0.75}$/d), NRC (1976) (540 KJ/kgBW$^{0.75}$/d) and when comparing this study with the other reports on *Bos taurus* cattle. It was found that this study was lower than report by DiCostanzo et al. (1991)(655 KJ/kgBW$^{0.75}$/d) and Unsworth et al. (1991)(670 KJ/kgBW$^{0.75}$/d).

Metabolizable energy and net energy for maintenance estimates vary widely and are not yet clarified, because there were many factors influence on energy requirement such as biological type, sex, stage and environmental conditions (NRC, 2000; Luo et al., 2004). In Thailand, a limited number of studies have attempted to define a suggested energy requirement and energetic efficiency. More energy research is needed to better define the requirement for beef cattle.

5.3.2 Energy requirement for maintenance and efficiency of energy utilization from long-term feeding trial studies

The metabolizable energy requirement for maintenance estimated using the relationship between MEI on ADG in this study indicated that, the overall estimate of maintenance requirement was higher than that determined based on the relationship between ER and MEI. The equations are shown in Table 5.2. A linear relationship of regressing ADG against MEI was obtained, MEI = 479.19 $_{(112.83)}$ + 27.40 $_{(9.25)}$ ADG (n=13, R^2=0.54, RSD=51.38, $P<0.05$) for steer (equation 5), MEI = 544.09$_{(86.07)}$ + 18.43

$_{(6.64)}$ ADG (n=11, R^2=0.89, RSD=63.19, *P<0.05*) for bull (equation 6) and MEI = 488.81 $_{(59.19)}$ + 26.67 $_{(5.34)}$ ADG (n=24, R^2=0.64, RSD=39.42, *P<0.001*) for pool data (equation 4). From the equation 4-6, the maintenance requirements of metabolizable energy were estimated to be 479.19 and 544.09 KJ/kgBW$^{0.75}$/d for steer and bull, respectively. The result from this study was in agreement with a report of Chizzotti et al. (2007), who found that ME_m of steer was lower than bull about 17%. Likewise, the difference of ME_m between bull and steer from the present study was similar to a report of Tedeschi et al. (2002), who indicated that bull required energy for maintenance higher than steer by about 5.04%. The analysis of pool data resulted in a common of maintenance requirement of 488.81 KJ/kgBW$^{0.75}$/d, which was 8.45% higher than the maintenance requirements estimate from energy balance studies of 450.71 KJ/kgBW$^{0.75}$/d. The ME_m from this finding was close to recommendation for Thai native cattle by WTSR(2008) (484 KJ/kgBW$^{0.75}$/d) and nearly identical to the ME_m of 498 KJ/kgBW$^{0.75}$/d for Nellore cattle by report of Tedeschi et al. (2002) and similar to Brahman crossbred cattle by report of Ferrell and Jenkin (1998) (488 KJ/kgBW$^{0.75}$/d), but higher than Malaysian Kedah Kelantan from report of Laing and Young (1995) (335 KJ/kgBW$^{0.75}$/d). However, energy requirement values can differ because of differences in feeding level, environmental condition length of measurement period and dietary characteristics (Mader et al., 2003; Freetly et al. 2006)

Table 5.1 Summary database of energy balance studies and long-term feeding trial Studies for prediction of metabolizable energy requirements for maintenance

Item	n	Mean	SD	Min	Max
Summary of energy balance studies					
All					
Body weight (kg)	62	199.69	39.38	149.00	297.00
Metabolic body weight (kgBW$^{0.75}$)	62	52.94	7.71	42.65	71.54
Metabolizable energy intake (KJ/kgBW$^{0.75}$/d)	54	514.61	106.01	285.60	783.93
Energy retention (KJ/kgBW0.^{75}/d)	54	51.71	108.07	-152.50	337.09
Steer					
Body weight (kg)	34	173.47	17.61	139.00	206.00
Metabolic body weight (kgBW$^{0.75}$)	34	47.75	3.64	40.48	54.38
Metabolizable energy intake (KJ/kgBW$^{0.75}$/d)	26	459.06	85.62	285.60	644.00
Energy retention (KJ/kgBW0.^{75}/d)	26	58.77	134.48	-152.50	337.09
Bull					
Body weight (kg)	25	229.68	38.87	179.00	297.00
Metabolic body weight (kgBW$^{0.75}$)	25	58.85	7.42	48.94	71.54
Metabolizable energy intake (KJ/kgBW$^{0.75}$/d)	25	580.46	89.59	456.07	783.93
Energy retention (KJ/kgBW0.^{75}/d)	25	27.85	62.62	-92.02	156.61
Summary of long-term feeding trial studies					
All					
Body weight (kg)	24	220.01	51.66	130.90	291.00
Metabolic body weight (kgBW$^{0.75}$)	24	56.83	10.15	38.70	70.46
Metabolizable energy intake (KJ/kgBW$^{0.75}$/d)	24	726.39	193.14	418.40	1012.74
Average daily gain (g/kgBW$^{0.75}$/d)	24	8.71	5.35	0.16	16.86
Steer					
Body weight (kg)	13	193.52	41.90	130.90	260.67
Metabolic body weight (kgBW$^{0.75}$)	13	51.67	8.46	38.70	64.87
Metabolizable energy intake (KJ/kgBW$^{0.75}$/d)	13	741.73	185.28	418.40	1012.74
Average daily gain (g/kgBW$^{0.75}$/d)	13	9.65	5.11	0.26	16.86
Bull					
Body weight (kg)	11	251.31	45.17	180.96	291.00
Metabolic body weight (kgBW$^{0.75}$)	11	62.93	8.69	49.34	70.46
Metabolizable energy intake (KJ/kgBW$^{0.75}$/d)	11	708.25	209.60	429.00	970.59
Average daily gain (g/kgBW$^{0.75}$/d)	11	7.60	5.65	0.16	15.47

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

Table 5.2 Regression of energy retention on ME intake and ME intake on average daily gain to describe energy utilization by Thai native steer and bull.

Eq.	Cattle	Response variables	Dependent factor	n	Parameter estimates				Model statistics			ME_m	k_{m}, %
					Intercept	SE	slope	SE	RSD	Adj.R^2	P		
energy balance studies													
1	All data	Energy retention	Metabolizable energy intake	62	-283.95	49.03	0.63	0.03	11.62	0.64	0.001	450.71	63
2	Steer	Energy retention	Metabolizable energy intake	34	-222.57	79.94	0.60	0.02	14.48	0.71	0.001	370.95	60
3	Bull	Energy retention	Metabolizable energy intake	25	-232.09	67.80	0.44	0.12	8.54	0.45	0.001	527.47	44
long-term feeding trial studies													
4	All data	Average daily gain	Metabolizable energy intake	24	488.81	59.19	26.67	5.34	39.42	0.64	0.001	488.81	
5	Steer	Average daily gain	Metabolizable energy intake	13	479.19	112.83	27.41	9.25	51.38	0.54	0.05	479.19	
6	Bull	Average daily gain	Metabolizable energy intake	11	544.09	86.07	18.43	6.64	63.19	0.89	0.05	544.09	

5.3.3 Accuracy of prediction equations

The accuracy of prediction equation were test by paired t-test, which are shown in Table 5.3. The accuracy evaluation of the model prediction by paired t-test between actual and predicted values in this study is shown in Table 5.3. A paired t-test between actual and predicted values was not-significant *(P>0.05)* for evaluated ME_m, which also indicated that calculated energy retention values using the derived prediction model matched well with the actual values in this study. The mean proportional bias was -17.00% to 11.74% for ME_m evaluation. Mean prediction error of equations was 1.25 to 5.84 which indicated that adequate accuracy of prediction across the database.

Table 5.3 The accuracy evaluation of equations for predicted metabolizable energy requirement for maintenance of Thai native cattle

Equations	Actual (A)	Predicted (P)	Residual (P-A)	Paired t-test A vs. P (P-value)	MPB (%)	MPE
energy balance studies						
1	16.03±17.21	0.09±15.40	-15.93±11.82	0.18	-17.00	5.84
2	-1.18±26.64	-7.04±21.22	-5.86±14.32	0.68	-5.72	1.25
3	-0.67±8.43	17.03±7.62	17.69±10.57	0.94	11.74	2.34
long-term feeding trial studies						
4	726.38±39.42	721.18±29.10	-5.19±22.04	0.82	-3.11	0.15
5	741.72±51.38	743.80±38.81	2.08±35.63	0.95	2.21	0.17
6	708.25±63.19	684.06±31.38	-24.18±34.93	0.50	-7.07	0.16

MPB = Mean proportional bias, MPE = Mean prediction error

5.4 Conclusions

In a balance trial, the results indicated that the metabolizable energy requirement for maintenance of Thai native cattle were 527.47 KJ/kgBW$^{0.75}$/d for bull, 370.95 KJ/kgBW$^{0.75}$/d for steer and 450.71 KJ/kgBW$^{0.75}$/d for pool data. The k_m values were 44% for bull, 60% for steer and 63% for pool data. In a long-term feeding trial, the results showed that the metabolizable energy requirement for maintenance of Thai native cattle was 544.09 KJ/kgBW$^{0.75}$/d for bull, 479.19 KJ/kgBW$^{0.75}$/d for steer and 488.81 KJ/kgBW$^{0.75}$/d for pool data. These results suggest that the energy requirements derived in the present study can be used as guidelines. The equation recommended was developed from a small database and this caused high variation. More feeding trials and balance trial are needed to better define energy requirements for beef cattle.