ENERGY UTILIZATION MODELS OF CATTLE GRAZING IN OIL PALM PLANTATIONS
I. DEVELOPMENT OF MODELS

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Summary

Energy obtained by grazing cattle in oil palm plantations is usually used for maintenance of body functions, the construction of body tissues and pregnancy, the synthesis of milk and the conversion to mechanical energy used for activities such as walking, eating and others. In this study, attempt was made to estimate metabolizable energy (ME) requirement of grazing cattle. Models of ME requirement (MER) for maintenance, gain, pregnancy, lactation and activities were developed. ME system and units were used because of wide recognition. Estimation of ME intake in grazing cattle was expressed as MEVI = 14.58 × VI × DMD, and under grazing condition MEVI = MER_i. MER was expressed as a function of net energy (NER, MJ) required for the i'th body function. Coefficient of efficiency for conversion of ME into net energy (ki) was adopted from literatures. Quantifying of ME requirement for Kedah-Kelantan cattle under grazing condition was made by using equation MERM = NEM / kn. The estimated values of MER for Kedah-Kelantan cattle is quite reasonable if compared with other estimates as reported in literatures from stall-fed animals. Dynamic MER models for grazing herd was developed in order to estimate ME requirement for maintenance and productions. These ME requirement models can be used for prediction of energy utilization pattern of the herd in the grazing systems.

(**Key Words** : Metabolizable Energy, Models, Grazing Cattle, Oil Palm Plantations)

Introduction

Metabolism in cattle is currently expressed in one of two ways derived from different systems of analysis: one based on metabolizable energy (ME), proposed by Blaxter (1962), adopted by the UK Agricultural Research Council (ARC, 1965) and put into practice by the Ministry of Agriculture, Fisheries and Food (MAFF, 1975): the other, based on net energy (NE), proposed by Lofgreen and Garrett (1968) and adopted by the USA National Research Council (NRC, 1970). The relative merits of each system have been reviewed by Webster (1978), he points out that "it does not matter which convention one uses provided that one recognizes that it is not possible to combine estimate of the energy value of foods from one system with estimates of energy requirements of the other and get a sensible answer". The reason is that the expressions are based on different conventions. For the purposes of this study, ME units have been chosen.

In general, herbage intake by cattle grazed extensively is influenced by the age and physiological status of individual animals, the quality and quantity of the available herbage and the environment, including management (Dahlan, 1989). Energy obtained by grazing cattle from the feed is usually used for a variety of purposes, including the maintenance of body functions, the construction of body tissues, the synthesis of milk and the conversion to mechanical energy used for activities such as walking, eating and others. Thus, in this study the calculation of intake required for all body function and its respectively energy requirement were specified accordingly.

The purpose of this study is to relate the physiological aspects of energy turnover of grazing cattle to the real-life situation as influenced by feed availability and quality in oil palm plantations. Emphasis will be placed on the energy utilization from herbage intake under various palm ages in order to meet the enrgy requirements of grazing cattle.

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Materials and Methods

Energy intake and utilizations in grazing cattle

The estimate of herbage intake in this study assume an *ad libitum* feeding regime and also adequate time for grazing. The usual method of estimating the voluntary forage intake of freely grazing animals is by faecal output (for instance, Conrad et al., 1964; Elliot and Fokkema, 1961; Hodgson, 1968; Dahlan et al., 1988). Dahlan, (1989) demonstrated that for freely grazing beef cattle in oil palm plantations, the ratio of kg DM faecal output (FO) over kg body weight (BW) is always constant (F-value) for each respective animal physiological states and feed quality.

$$F = FO / BW \quad (1)$$

Daily intake or voluntary intake (VI) and daily faecal output (FO) are related as

$$FO = VI \times (1 - DMD) \quad (2)$$

where DMD is the digestibility fraction of the forage consumed. VI is usually expressed on basis of body weight (BW).

$$VI = F \times BW / (1 - DMD) \quad (3)$$

Using the respective F-values and calculated VI, metabolizable energy intake per day (MEVI) can be estimated based on the following equation

$$MEVI = GE \times VI \times q \quad (4a)$$

where GE is feed gross energy content and q is feed energy concentration or metabolizability. Since the proportion of digestible energy losses of about 19% as urine and methane (Armstrong, 1964; MAFF, 1975), and metabolizable energy (ME) can be expressed as a function of GE, thus the digestibility of the consumed herbage is approximately as

$$q = (1 - 0.19) \times DMD$$

$$q = 0.81 \times DMD \quad (4b)$$

Thus, the ME obtained from VI can be expressed as

$$MEVI = GE \times VI \times 0.81 \times DMD \quad (4c)$$

The GE contents of different herbages are very similar, at about 18 MJ/kg dry matter (DM) (Hunt, 1966; Minson and Milford, 1966). Dahlan (1989) showed that the analysis of GE contents of 73 herbage species found under oil palm plantations gives the value of 16.3 to 18.4 MJ/kg DM. Thus, GE value of 18 MJ/kg DM was used in the calculation of MEVI of grazing cattle in oil palm plantations.

$$MEVI = 18 \times VI \times 0.81 \times DMD$$

$$\text{or } MEVI = 14.58 \times VI \times DMD \quad (4d)$$

The conversion of metabolizable energy into net energy is also associated with some losses as heat, which depends on the quality of the consumed feed and the body function for which the energy is utilized.

In the most general case, energy use in an animal can be accounted for its requirements for maintenance, lactation, pregnancy and growth. Thus, conversion of metabolizable energy (ME) to net energy is described by the relationship

$$NER_i = k_i \times MER_i \quad (5a)$$

Under grazing conditions, feed are assumed *ad libitum*, thus, the animal will graze according to its requirement as

$$MEVI = MER_i$$

$$\text{Thus, } NER_i = K_i \times 14.58 \times VI \times DMD \quad (5b)$$

where NER_i is net energy (MJ) required for the i'th body function, k_i is coefficient of the efficiency of conversion of metabolizable into net energy for the i'th body function. And daily feed intake can be expressed as

$$VI = NER_i / (k_i \times 14.58 \times DMD) \quad (6)$$

Thus, for the calculation of intake required for the i'th body function, net energy requirement (NER_i) and the efficiency coefficients (k_i) need to be specified.

Estimates of ME requirements for grazing cattle

In this study, the ME requirements (MER) of grazing cattle was classified according to the need of body functions such as for maintenance and activities, body weight gain or growth, pregnancy and lactation.

For growing animals (calf, heifer and steer) the ME intake is utilized for maintenance, activities and body weight (BW) gain. The metabolizable energy requirement of growing animal (MERgr) can be expressed as follows:

$$MERgr = MERM + MERG \quad (7)$$

where MERM is ME for maintenance requirement including activities and MERG is ME for body weight gain.

For cow (cycling cow and mature heifer), the ME intake is utilized for maintenance, activities and pregnacy. The expression is as folllws:

$$MERpc = MERM + MERP \quad (8)$$

where MERP is ME for pregnancy requirement.

In lactating cow, the ME intake is utilized for maintenance, activities and lactation. The expression is as follows:

$$MERlc = MERM + MERL \quad (9)$$

where MERL is ME for lactation.

If the cow is pregnant and also nursing the calf, the ME intake is utilized for both pregnancy and lactation besides its maintenance requirement. Thus, the requirement of ME in the cow can be expressed as

$$MERlpc = MERM + MERP + MERL \quad (10)$$

And for the bull, the ME intake is utilized mainly for maintenance and activities.

$$MERbull = MERM \quad (11)$$

In grazing cattle, the energy needed for activities such as walking and eating should be considered especially if the feed availability from the field is quite scarce. Ribeiro (1976) cited by ARC (1980) reported that the energy cost of walking per km is about 0.0021 MJ/kg. Finch and King (1979) mentioned that the energy cost of walking per horizontal km is similar for *Bos taurus* and *Bos indicus* cattle on a diet at or above maintenance. The cost of prehension, tearing and eating coarse dry grass has been estimated at 40 kJ/MJ ME of ingested food, based on Webster (1980). The energy cost of activities should be included together as the daily maintenance requirement of grazing animals.

Estimates of maintenance requirements

The amount of ME used for maintenance (MERM) in the zebu cattle can be estimated from the equation

$$\text{MERM} = \text{NEM} / \text{kn} \quad (12)$$

where NEM is net energy requirements for maintenance (MJ/day) and kn is the efficiency with which ME is used for maintenance. The kn can be expressed as a function of the metabolizability (q) of the consumed feed (as reported by Blaxter, 1974; MAFF, 1975 and Pigden et al., 1979 in ARC, 1980) as follows:

$$\text{kn} = 0.546 + 0.30 \times q \quad (13)$$

Following Blaxter (1969) and Webster (1978), total net energy requirements for maintenance (NEM) can be obtained from the relationship

$$\text{NEM} = 0.376 \times \text{BW}^{0.73} + 0.0021 \times \text{BW} \times \text{WD} \quad (14)$$

where BW is body weight (kg) and WD is walking distance (km/day). Hence, MERM can be expressed as a function of BW, herbage quality and also activity (WD) when substituting equations (13) and (14) into equation (12). By substituting equation (13) and (14) into equation (6) yields the feed requirements needed to meet energy for maintenance. Based on these equations the quality of feed required for maintenance is related to animal's BW, activities and also feed or herbage quality.

Estimates of energy requirements for gain

The ME requirement for gain (MERG) can be estimated from the equation

$$\text{MERG} = \text{NEG} / \text{kgn} \quad (15)$$

where NEG is net energy requirements for body weight gain (MJ/day) and kgn is the efficiency with which ME is converted into energy for BW gain. Blaxter (1973) showed that kgn is related to metabolizability of the feed (q) by the relationship

$$\text{kgn} = 0.81 \times q + 0.03 \quad (16)$$

NEG depend in general on both the BW gain achieved and the animal's present BW. A relationship suggested by MAFF (1975) is

$$\text{NEG} = \text{DG} \times (6.28 + 0.0188 \times \text{BW}) / (1 - 0.3 \times \text{DG}) \quad (17)$$

where DG is daily gain (kg/day).

Hence, MERG can be expressed as a function of BW, DG and also herbage quality, when substituting equations (16) and (17) into equation (15).

Daily gain of grazing animal can be estimated based on equation (17) as follows:

$$\text{DG} = \text{NEG} / (6.28 + 0.0188 \times \text{BW} + 0.3 \times \text{NEG}) \quad (18)$$

By substituting of equations (16) and (17) into equation (6), the feed requirements for BW gain can be obtained.

Estimates of energy requirements for pregnancy

The ME requirement for pregnancy can be estimated from the equation

$$\text{MERP} = \text{NEPi} / \text{kpi} \quad (19)$$

where NEPi is net energy requirement for i'th stage of pregnancy and kpi is the efficiency with which ME is converted into energy for i'th stage of pregnancy.

During pregnancy, cattle usually gain in BW due to the growth of the foetus and uterus together with the growth of the mammary gland. Net energy requirements for pregnancy involve the energy deposited in the uterus and associated tissues (NEP1), the energy associated with synthetic processes involved in foetal growth (NEP2), the energy required for foetal maintenance and the increased maternal fasting metabolism occurring during pregnancy (NEP3). Thus, total NEP as given by MAFF (1975) is defined as

$$\text{NEP} = \text{NEP1} + \text{NEP2} + \text{NEP 3} \quad (20)$$

where $\text{NEP1} = 0.03 \times \exp(0.0174 \times \text{TC}) \quad (21)$

$$\text{NEP2} = 0.452 \times \exp(0.01 \times \text{TC}) \quad (22)$$

and $\text{NEP3} = \text{NEP2} \quad (23)$

TC is time (days) after conception.

The efficiency with which ME is converted into NEP depends on the different end uses of this energy. MAFF (1975) described the following effeciency coefficients for respective NEPi as follows:

$$\text{kp1} = \text{kp2} = 1.0 \quad (24)$$

$$\text{kp3} = \text{kn} \quad (25)$$

Where kn is the coefficient of converting ME into NEM given by equation (13). Hence, the MERP can be expressed as follows:

$$\text{MERP} = \text{NEP1} + \text{NEP2} + \text{NEP3} / \text{kp3} \quad (26)$$

Substituting the values of equations (20), (24) and (25) into equation (6) yields the feed requirements needed to meet energy for pregnancy.

Estimates of energy requirements for lactation

The ME requirement for lactation can be estimated from the equation

$$MERL = NEL / kl \quad (27)$$

where NEL is net energy requirements for lactation (MJ/day) and kl is the efficiency with which ME for lactation is converted into NEL. The kl is less than that for maintenance. Pigden et al. (1979) suggested the relationship of kl with q as

$$kl = 0.463 + 0.24 \times q \quad (28)$$

Thus, the efficiency is related to metabolizability (q) of the feed. MAFF (1975) suggested the value of kl being about 0.60.

The net energy requirements for milk are calculated from the milk yield (MY, kg/day) multiplied by its energy content (EL, MJ/kg). Hence, the NEL is approximately proportional to the quantity of milk produced

$$NEL = EL \times MY \quad (29)$$

The energy content of milk is given approximately by the following equation (MAFF, 1975)

$$EL = 0.0386 \times BF + 0.0205 \times SNF - 0.236 \quad (30)$$

where BF is butter fat content (g/kg), and SNF is solid-not-fat content (g/kg). For the zebu, BF = 54 g/kg and SNF = 85 g/kg (Williamson and Payne, 1978), the calculated energy content of milk is 3.6 MJ/kg. For Kedah-Kelantan (KK) cows, BF = 35.1 g/kg and SNF = 95 g/kg (Lee and Devendra, 1978) and the calculated energy content of KK's milk according to equation (29) is 3.07 MJ/kg. Substituting the values of equation (28), (29) and (30) into equation (6) yields the feed requirements to produce a given quantity of milk of a certain energy content.

Estimation of daily milk yield of grazing beef cattle

Daily milk yield of beef cow is very difficult to measure especially under grazing conditions. Thus, estimation of milk yield (MY) should be based on total MY per lactation and number of days after parturition. MY of a cow for the n'th day postpartum can be expressed as a fraction of the potential yield for the whole lactation. It is assumed in the model that the average daily MY is constant over the first 60 days of lactation and declines linearly thereafter. According to Wood's lactation curve (Wood, 1969), the fraction of MY produced during the first 60 days is about 35% of potential yield (PMY) for the whole lactation. Thus, the daily MY (MY1, kg/day) for the first 60 days of lactation can be estimated as

$$MY1 = PMY \times 0.35 / 60 \quad (31)$$

This equation only applies to lactation day (DL) of less or equal to 60 days postpartum.

The daily MY (MY2, kg/day) for DL more than 60 days postpartum can be estimated as

$$MY2 = MY1 - MY1 / 210 \times (DL - 60) \quad (32)$$

with the assumption that the lactation length of beef cow is about 9 months (270 days). The model of milk yield can be used for grazing beef cows for estimation of daily milk yield and also daily ME requirement during lactation according to the quantity of milk predicted.

Estimates of energy released from mobilization of body reserves

Usually in grazing cows, weight loss occurs during and after calving. Cow body weight loss during calving occurs by the loss of weight due to born calf, tissues and amniotic fluids and also some blood. In small size cows such as Kedah-Kelantan cattle, the weight loss will be about 20 to 30 kg during parturition. After parturition, the cow will nurse the calf and during the early lactation stage the energy requirement of the cow is usually very high due to maintenance, activities, lactation and also pregnancy requirements if the cow conceive again within 60 days of calving. When energy derived from feed intake is insufficient to meet the animal's total energy requirements due to physical limitation of the gut volume and also low quality and may be quantity of the available feed, then the energy balance is achieved by the mobilization of body reserves.

The energy value of the tissue mobilised is taken as 20 MJ/kg (MAFF, 1975), although the mean value for the meat in carcass may be lower (Ledger and Sayers, 1977). The coefficient for its utilization is 0.82, the net energy available (NET) from the mobilization of body tissue is

$$NET = 20 \times 0.82 \times DW$$

$$NET = 16.4 \times DW \quad (33)$$

where NET is net energy available for maintenance, pregnancy or lactation (MJ). The DW is mobilized body tissue (kg). The amount of body tissue (kg) needed to meet a net energy deficit (NET) is given by the inverse :

$$DW = NET / 16.4 \quad (34)$$

The mobilization of body tissue will occur when the metabolizable energy intake (MEVI) is less than metabiolizable energy requirement (MER). Hence, changes in body weight of grazing cattle can be expressed as

$$WC = (MEVI - MER) / 16.4 \quad (35)$$

where WC is body weight changes (kg/day) due to tissue mobilization. If the value of MEVI $<$ MER, weight loss will occur in the grazing animal. The body weight changes of grazing animal can be simulated according to this models.

Results and Discussion

Quantifying ME requirements of Kedah-Kelantan (KK) cattle under grazing condition

a. Maintenance requirement

Most of the values on energy requirements for maintenance of cattle were estimated based on stall-fed animals. Measurement of ME requirements of grazing cattle is very difficult. Devendra (1980) estimated that the mean maintenance requirement of KK bulls on stall-fed was 615.9 kJ ME/kg $BW^{0.75}$/day. Liang et al. (1988) estimated the maintenance requirement of KK heifers was about 662 kJ ME/kg $BW^{0.75}$/day and Brahman × kk heifers was 494 kJ ME/kg $BW^{0.75}$/day. Kearl's (1982) estimate of the maintenance requirement of *Bos indicus* non-lactating cows was about 494 kJ ME/kg $BW^{0.75}$/day.

By use of equation (12), the estimation of maintenance requirement of grazing KK cattle with average walking distance about 5.5 km/day as based on observation of cattle grazing in oil palm plantations (Dahlan, 1989) was 583 kJ ME/kg $BW^{0.75}$/day for all cattle age and sex. Considering the energy cost of walking (5.5 km required 11.55 kJ/day) and the cost of prehension, tearing and eating the herbage (required about 0.46 kJ/day), the estimated maintenance requirement of KK cattle (substracting the energy cost of activities as 12.01 kJ/day) is about 571 kJ ME/kg $BW^{0.75}$/day. Recent findings on maintenance requirements of cows of different breed types as reported by Solis et al. (1988) showed very high variations in the maintenance requirements of cows of different breed types, with a range from 372 kJ ME/kg $BW^{0.75}$/day of Angus × Brahman cows to 636 kJ/kg $BW^{0.75}$/day of Jersey cows. They concluded that differences between body composition and physiological priorities between beef and dairy breeds significantly influence maintenance requirements and efficiency of energy use, and also maintenance requirements for weight and energy equilibrium were lower in beef breeds and their crosses than in dairy breeds and their crosses. The estimated value of maintenance requirement of KK cattle based on equation (12) is quite reasonable if compared with other estimates reported by various researchers for stall-fed *Bos indicus* cattle (Devendra, 1980 and Liang et al., 1988).

b. Metabolizable energy (ME) requirement for maintenance and production of grazing herd

Since the predicted ME requirement for maintenance of KK cattle showed some agreement with other reported values, the model of energy utilization can be adopted in order to quantify the ME (MJ) requirements of the grazing herd for maintenance and production.

Table 1 shows the predicted ME requirement of various cattle status in cow-calf herd in the grazing system. By specifying the initial body weight, activities and animal's physiological status, the ME requirement of the grazing herd can be predicted according to the energy utilization models.

TABLE 1. METABOLIZABLE ENERGY REQUIREMENTS (MER) OF COW-CALF HERD IN THE GRAZING SYSTEM

Status	Body wt. (kg)	ADG (kg /day)	MERM (MJ /day)	MERG (MJ /day)	ME requirement (MJ /day)
Preweaners	19.5	0.35	5.33	8.04	13.37
Weaners (F)	82.0	0.30	15.68	7.98	23.66
Weaners (M)	82.0	0.35	15.68	9.46	25.14
Heifers	136.0	0.30	23.00	9.01	32.00
Bull calves	146.0	0.35	24.28	9.92	34.20
Pregnant cow	212.0	0.12	32.23	3.95	45.57*
Lactating cow	212.0	0.00	32.23	0.00	58.37**
Dry cow#	212.0	0.00	32.23	0.00	32.23
Bull@	550.0	0.00	66.85	0.00	66.85
Total herd ME requirement					331.39
Mean herd ME requirement					36.82+

* Including MERP = 9.39 MJ/day at TC = 200 days

** Including MERP = 9.39 MJ/day and MERL = 16.76 MJ/day with average milk yield of 3.5 kg/day.

\# Non pregnant cow.

@ Brahman bull.

\+ Mean herd ME requirement was considered equivalent to 1 animal unit ME requirement (AUE).

MERM - ME requirement for maintenance including ME requirement for grazing 5.5 km/day. MERG - ME requirement for body weight gain. MERP - ME requirement for pregnancy. MERL - ME requirement for lactation.

The ME requirement for maintenance (MERM) is mainly dependent on the animal body weight and activities such as walking and eating. Thus, for large size bull i.e., Brahman bull, the MERM is very high and it accounts for more than twice the requirement of dry KK cow. In order to determine the carrying capacity of the grazing area, the body weight of the animal or breed type should be considered. For smaller breed type, the carrying capacity per hectare will be higher and the ME requirement per animal will be lower if compared with larger breed type of cattle.

Ferrell and Jenkin (1984) showed that approximately 70% of the energy required to maintain the cow-calf herd can be attributed to energy cost for cow-calf maintenance and about 50% of the total feed energy required for beef production is for maintenance. Since MERM represents a major portion of the feed required for beef production, the MERM of the specific breed of animal should be considered in the process of decision making for cow-calf herd grazing system enterprise.

The predicted mean of herd ME requirement can be assumed as equivalent to one representative unit of animal in the grazing herd or one animal unit equivalent (AUE). Thus, one AUE required about 36.82 MJ ME/day. This AUE will be used for prediction of carrying capacity of beef cattle in oil palm plantations.

Dynamic ME requirement of the grazing herd

The energy requirement for maintenance and production of the grazing herd is a dynamic process. The body weight of the animal changes according to age and also physiological status, thus, the MERM and ME requirements for productions also changes accordingly. For example, the ME requirement of the cow will change according to its production cycle i.e., pregnancy, lactation and dry period. In the development of dynamic ME requirements, these changes should be considered together with time factor.

The model for dynamic ME requirement of male and female calves can be calculated as follows:

$$MERc = MEiw + MEgain \times Delt \quad (36)$$

where MERc is daily ME requirement of the calf (MJ) MEiw is initial ME requirement according to initial body weight (MJ), MEgain is ME requirement for daily gain (MJ/day) and Delt is the time increment in days.

For male Brahman × KK (BK) calf, the MERc model started from birth to 16 months of age and can be expressed as

$$MERcm = 13.37 + 0.063 \times Delt \quad (37)$$

and female BK calf is as follows:

$$MERcf = 13.37 + 0.051 \times Delt \quad (38)$$

The dynamic model for calculating ME requirement in cow can be expressed as follows:

For dry cow:

$$MERdc = MEdc \times Delt \text{ and } Delt < 90 \text{ days} \quad (39)$$

where MERdc is daily ME requirement of dry cow (MJ) MEdc is ME requirement of dry cow according to its initial body weight (MJ/day).

For KK cow (dry cow body weight = 212 kg) the daily ME requirement can be expressed as

$$MERdc = 33.17 \times Delt \quad (40)$$

For pregnant cow:

$$MERpc = MEpc + MEp \times (Delt - 90)$$

$$Delt = 90 < 360 \text{ days} \quad (41)$$

where MERpc is daily ME requirement of pregnant cow (MJ), MEpc is ME requirement of pregnant cow according to initial body weight (MJ/day).

MEp is ME requirement for pregnancy according to day after conception (MJ/day).

Example for KK cow (body weight = 212 kg):

$$MERpc = 33.17 + 0.075 \times (Delt - 90) \quad (42)$$

For lactating cow:

$$MERlc = MElc + MEmy \times Delt$$

$$Delt < 210 \text{ days} \quad (43)$$

where MERlc is daily ME requirement of lactating cow (MJ), MElc is ME requirement for maintenence of lactating cow (MJ) and MEmy is ME requirement for lactation according to milk yield/day. Example for KK cow (body weight = 212 kg and milk yield = 3.75 kg/day where ME required to produce 3.75 kg milk per day = 20.92 MJ):

$$MERlc = 33.17 + 0.0996 \times Delt \quad (44)$$

For bull:

$$MERbull = MEbull \times Delt \quad (45)$$

where MERbull is daily ME requirement for maintenance and activities of bull (MJ), MEbull is ME requirement of the bull according to body weight and activities (MJ/day). Example for Brahman bull (body weight = 550 kg and walking 5.5 km/day):

$$MERbull = 66.85 \times Delt \quad (46)$$

In conclusion, this paper demonstrated that metabolizable energy requirement (MER) of grazing cattle including animals that graze in oil palm plantations can be estimated by using parameter values such as voluntary intake (VI), metabolizability (q) and gross energy content of the herbage (GE = 18 MJ/kg DM). MER for grazing cattle is a summation of energy requirement for maintenance, work and activities, growth, pregnancy and/or lactation. MER models developed in this study can be used to predict the quantity of energy requirement for cattle. The estimated values of maintenance requirement for Kedah-Kelantan cattle derived from MER models was about 571 kJ ME/kg $BW^{0.75}$/day. The value is quite similar to the other findings which was estimated based on stall-fed animals. Since the predicted MER for maintenance of Kedah-Kelantan cattle in this study showed some agreement with literature values, the MER models can be adopted for quantifying ME (MJ) requirements of the grazing herd in oil palm plantations for maintenance and production.

Literature Cited

ARC (Agriculture Research Council). 1965. The nutrient requirements of farm livestock. 2. Ruminants. London, HMSO. Section 6. 193-257.

ARC (Agriculture Research Council). 1980. The nutrient requirements of ruminant livestock. C.A.B., Slough, England. Armstrong, D. G. 1964. Evaluation of artificially dried grass as a source of energy for sheep. 2. J. Agric. Sci. Camb. 62:399-417.

Blaxter, K. L. 1962. The energy metabolism of ruminants. Hutchinson, London.

Blaxter, K. L. 1969. The efficiency of energy transformations in ruminants. In Energy Metabolism of Farm Animals. Eds. K. L. Blaxter, J. Kielanowski and G. Thorbek. London. pp. 21-28.

Blaxter, K. L. 1973. Metabolizable energy and feedings systems for ruminants. In Proc. of Nutr. Conf. For Feed Manufacturers. Eds. H. Swan and D. Lewis. No. 7 Univ. of Nottingham, London.

Blaxter, K. L. 1974. Energy metabolism of farm animals. 6th symp. Hohenheim, 1973. Eds. K. H. Menke, H. J. Lantzsch and J. R. Reich. Publ. Eur. Ass. Anim. Prod. 14. 115 p.

Conrad, H. R., A. D. Pratt and J. W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Change in the importance of physical and physiological factors with increasing digestibility. J. Dairy Sci. 47:54-162.

Dahlan, I. 1989. Modeling and Simulation of Herbage and Cattle Production Systems under Oil Palm Plantations in Malaysia. Ph.D. dissertation. Kyoto Univ., Japan. 230 pp.

Dahlan, I., M. D. Mahyuddin, Y. Yamada and J. B. Liang. 1988. Voluntary dry-matter intake of grazing cattle under oil palm plantation. In Maximizing Livestock Productivity. Proc 11th annual conf. Malaysian Society of Animal Production. IPT, Univ, Malaysia, Kuala Lumpur.

Devendra, C. 1980. The energy requirements for maintenance of stall-fed Kedah-Kelantan cattle in Malaysia. MARDI Res. Bull. 8(2):267-279.

Elliot, R. C. and K. Fokkema. 1961. Herbage consumption studies on beef cattle. Part I. Rhod. Agr. J. 58:49-57.

Ferrell, C. L. and T. G. Jenkin. 1984. Energy utilization by mature, non-pregnant, non-lactating cows of different types. J. Anim. Sci. 58:234-245.

Finch, V. A. and J. M. King. 1979. Adaptation to under-nutrition and water deprivation in the African zebu: Changes in energy requirements. Res. coordination meeting on water requirements of tropical herbivores based on measurements with tritiated water. Nairobi, Kenya. IAEA, Vianna.

Hodgson, J. 1968. The relationship between the digestibility of a sward and the herbage consumption of grazing calves. J. Agric. Sci. Camb. 70:47-51.

Hunt, L. A. 1966. Ash and energy content of material from seven forage grasses. Crop Sci. 6:507-509.

Kearl, L. C. 1982. Nutrient requirements of ruminants in developing countries. Intl. Feedstuffs Institute. Utah State University, Logan, USA. pp. 99-100.

Ledger, H. P. and A. R. Sayers. 1977. The utilization of dietary energy by steers during periods of restricted food intake and subsequent realimentation. J. Agric. Sci. Camb. 88:11-26.

Lee, K. C. T. and C. Devendra. 1978. Effect of protein levels on Kedah-Kelantan heifers during pregnancy and lactation. III. Effect on milk yield and milk composition. MARDI Res. Bull. 6(2):192-201.

Liang, J. B., M. N. Somiyah and H. Hirooka. 1988. Energy requirements for growing Kedah-Kelantan (KK) and Brahman-KK heifers in Malaysia. MARDI Res. J. 16(2):163-170.

Lofgreen, G. P. and W. N. Garrett. 1968. A system for expressing net energy requirements. J. Anim. Sci. 27:793-806.

MAFF (Ministry of Agriculture, Fisheries, and Food). 1975. Energy allowances and feeding systems for ruminants. Technical bull. no. 33, 79 p.

Minson, P. J. and R. Milford. 1966. The energy value and nutritive value indices of Digitaria decumbens, Sorghum almum, and Phaseolus atropurpureus. Aust. J. Agric. Res. 17:411-423.

NRC (National Research Council). 1970. Nutrient requirements of domestic animals. No. 4. Nutrient requirements of beef cattle. National Academy of Sciences. Washington, DC.

Pigden, W., C. C. Balch and M. Graham. 1979. Standardization of analytical methodology for feeds. In proc. of workshop. Ottawa, Intl. Dev. Res. Center.

Solis, J. C., F. M. Byers, G. T. Schelling, C. R. Long and L. W. Greene. 1988. Maintenance requirements and energetic efficiency of cows of differfent breed types.

J. Anim. Sci. 66:764-773.

Webster, A. J. F. 1978. Prediction of energy requirements for growth in beef cattle. Wld. Rev. Nutr. Diet. 30:189-226.

Webster, A. J. F. 1980. Energy cost of digestion and visceral metabolism. In Digestive Physiology and Metabolism in Ruminants. Lancester, MTP Press. pp. 469-484.

Williamson, G. and W. J. A. Payne. 1978. An introduction to animal husbandry in the tropics. London, Longman.

Wood, P. D. P. 1969. Factors affecting the shape of the lactation curve in cattle. Anim. Prod. 11(3):307-316.