ENERGY UTILIZATION MODELS OF CATTLE GRAZING IN OIL PALM PLANTATIONS
Ⅱ. VALIDATION OF MODELS

I. Dahlan[1], M. D. Mahyuddin and Y. Yamada

Department of Animal Science, Universiti Pertanian Malaysia, 43400 Serdang, Selangor, Malaysia

Summary

This study showed that models of energy utilization (EU) developed for grazing cattle in oil palm plantations is valid as the simulated results shows an agreement with actual data of calves and cows body weight changes collected from Brahman x Kedah-Kelantan herd in Pengeli Timor Plantation. Simulation runs on EU models demonstrated that the growth pattern of male and female calves and the weight changes of cows are similar and showed slight variation from the actual data but with no significant difference ($p > 0.05$). Parameter values such as metabolizability (q), dry matter digestibility (DMD) of herbage and voluntary intake of grazing cattle (VIG) and faecal output/body weight ratio (F) of the animals which were collected from the field are essential in bearing the pattern of body weight changes of the calves and cows in relation to increase in time, physiological status and quality of herbage grazed by these animals in the production system. The EU models is suitable for determining the metabolizable energy requirements and to predict the production of grazing cattle according to quality of the feed on offer.

(**Key Words** : EU Models, Validation, Calves, Cow, Grazing, Plantations)

Introduction

Model validation is an integral component of the modeling process, the criteria in which validity is assessed reflect the several stages of the modeling process. Validity is a multidimensional concept reflecting model purpose, current theories, and experimental test data relating to the particular system of interest, together with other relevant knowledge (Carson et al., 1983). Without proof of validity, a model, may be nothing but a tentative exercise in abstract logic (Hillel, 1977).

A model is scientifically valid if its assumptions conform to basic scientific principles. If a model is to portray a real system, then it must incorporate the major processes and phenomena which govern the system's behaviour. In the present study we are trying to validate some of the components in the sub-system of cattle grazing system under oil palm plantations such as body weight changes.

Materials and Methods

a. Data sources

Since the present model is consisted of many different sub-systems and components, it is practically impossible to obtain data which specify a particular system in sufficient detail so that the model predictions of the system can be compared with the actual outputs of the system. For instance, recorded data on grazing herds under oil palm plantations, if there is any, is always incomplete and usually consisted of information such as the number of the animal in the herd, number of death, number of sales and occasionally animal weights usually at the time of sales. Other information is very difficult to obtain under this extensive cattle grazing system.

Furthermore, there is no reported data available regarding the performance of cattle herd under such system in the literature. Thus, in this study validation of grazing cattle performance under oil palm plantation will be carried out mainly in terms of body weight gain of growing animals and also body weight changes of cows due to pregnancy and lactation. Data of Kedah-Kelantan (KK) cows and Brahman × KK calves from Penggeli Timor (PT) plantation in Johore State (latitude 1° 80' N and longitude 103° 60' E) will be used for the validation purposes. The data were collected from 'MARDI – FELDA Beef Cattle Integration Project' (1985 to 1988).

[1]Address reprint requests to Dr. I. Dahlan, Department of Animal Science, Universiti Pertanian Malaysia, 43400 Serdang, Selangor, Malaysia.

Received March 30, 1994
Accepted September 26, 1994

b. Data on performance of KK cattle herd in PT plantation

In the early 1985, about 53 KK cows and one pure Brahman bull were sent to this plantation for the purpose of setting up an 'intermediate herd' of Brahman × KK (BK) breedtype for the beef cattle breeding programme. Data such as monthly body weight, pregnancy rate, calving date, and mortality are available. After about 3.5 years in the plantation, the total number of cattle in the herd become 207 heads i.e., 50 cows, 1 bull and 156 progenies.

Table 1 shows the performance of Brahman × KK calves under oil palm plantation. Birth weight to 6 months weight of male and female calves showed no significant difference, although female calves always showed lower body weight than male calves during these ages. After 9 months of age, male calves showed higher ($p < 0.05$) body weight than female calves. The average daily gain (ADG) of the calves below 18 months of age showed highest value at the age of 9 months for male and 6 months for female. At 18 months of age all male calves were separated from the herd, for fattening purposes (kept in feedlot). During the earlier stage in the feedlot (about 2 weeks) the male calves lost their body weight. This is due to adaptation to the new feed. But after that the bull calves showed very high ADG. The female calves showed a decline in ADG up to 18 months of age when they passes the age of puberty, but most of the heifers showed increase in ADG at 21 months of age and onward. This is because some of the heifers had become pregnant at this age. Thus the increase in ADG is mostly due to the increase in weight owing to pregnancy. The mortality rate of calves was nil in the first breeding year, but in second year the mortality rate was 11.6%. The sex ratio of the calves born was 1:0.91 for male to female ratio.

Table 2 shows the performance of KK cows under oil palm plantation. The mean body weight of KK cows was 212.5 kg and there was a high variation in body weight of these cows mainly due to the changes in its physiological stages (pregnancy, lactation or dry stages). Mean calving interval was about 13 months and mean calving percentage was about 80.4%. Mortality in the cows was very low and most cases due to accidental death, not by natural causes. Culling was carried out in one cow due to infertility problem. At any time in the year about 50% of the cows were pregnant under this continuous mating system. The ratio of bull to cows in this herd was 1:50 and based on the pregnancy rate of 50%, the ratio of bull to receptive cow at any time in the year was 1:25.

These information will be used in the validation processes in order to compare the real system data with the simulated result.

TABLE 1. PERFORMANCE OF BRAHMAN × KEDAH-KELANTAN CALVES UNDER OIL PALM PLANTATION

Age (month)	Male calf				Female calf			
	n	Mean BW (kg)	s. d.	ADG (kg / day)	n	Mean BW (kg)	s. d.	ADG (kg / day)
Birth*	27	18.8	2.7	–	12	18.6	2.5	–
Birth#	16	22.2	3.0	–	27	19.2	4.4	–
Birth@	43	20.5	2.8	–	39	18.9	3.5	–
3	7	52.4	8.5	0.354	11	48.3	7.3	0.326
6	10	85.6	17.9	0.369	15	78.5	15.8	0.335
9	14	122.1	23.5	0.405	18	108.1	21.5	0.328
12	16	145.3	24.6	0.258	15	131.6	23.1	0.261
15	14	173.3	27.8	0.311	14	148.9	21.8	0.192
18**	14	186.1	37.6	0.143	8	164.5	20.9	0.173
21	11	245.6	54.1	0.662***	11	203.8	38.6	0.437##
24	7	270.9	24.4	0.281***	4	229.5	15.6	0.286

Calf mortality	1986	1987	Overall value	
Male calf	0	2	Mortality in 1987	11.6%
Female calf	0	3	Sex ratio (M:F)	1 : 0.91

* 1986 calves, # 1987 calves, @ mean values ; ** Male calves put in feedlot (adaptation period) ; *** Better gain due to feedlot feeding. ## Some of heifers become pregnant at the age of 21 month. ADG - average daily gain ; BW - body weight ; n - number of animal ; s.d. - standard deviation.

TABLE 2. PERFORMANCE OF KEDAH-KELANTAN COWS UNDER OIL PALM PLANTATION

Parameter		n	Mean	s. d.	Minimum	Maximum
Body weight (kg)		51	212.5	27.5	150.4	289.0
Calving interval (days)		18	391.5	57.6	304	498
			Year			
		1986		1987	Mean	
Calving (%)		76.5		84.3	80.4	
Mortality (%)		1.8		3.8	2.8*	
Culling (%)		1.8		0	1.8**	
Date	10/86	4/87	11/87	1/88	4/88	Mean
Pregnancy (%)	47.1	54.9	74.5	54.9	35.3	53.3

* Due to traffic accident
** Infertility problem.

Validation of calves' growth based on model-calculated energy intake

a. Simulation of preweaners growth

In order to simulate the calf growth or body weight changes, initial body weight, time increment and parameters of energy intake models of the calf need to be specified. Male and female calves (preweaners) were assumed to have similar growth rate during their first 6 months of age because they received similar quantity and quality of milk from the cow.

Parameter values of calves below 6 months of age (preweaners) are:

Birth weight (LWC) = 19.5 kg (mean birth weight of male and female Brahman × KK calves)

Kgn = 0.323 [efficiency of converting net energy to ME for gain based on MAFF (1975)].

DMD = 0.765 (Mean digestibility value of milk and herbage under oil palm plantation)

F-value = 0.00846 (ratio of kg body weight/kg faecal output in calves)

Delt (time increment) = 30 days (accumulated from 1 day time increments in order to compare with monthly data collected from the real system)

Voluntary intake of preweaning calves (VIG) was simulated according to model :

$$VIG = F \times LWC/(1\text{-}DMD) \quad (1)$$

Net energy for gain according to model :

$$NERG = 14.6 \times Kgn \times VIG \times DMD \quad (2)$$

Daily gain of the calf (DGC) was simulated according to model :

$$DGC = NERG/(6.28 + 0.0188 \times LWC + 0.03 \times NERG) \quad (3)$$

and increment of body weight of calf was simulated according to model :

$$LWC-Delt_i = LWC-Delt_{(i-1)} + DGC \times 30 \quad (4)$$

Where $LWC-Delt_i$ is body weight at i'th age (by 30 days increment) and $LWC-Delt_{(i-1)}$ is body weight at (i-1)'s the age or initial body weight.

b. Simulation of body weight changes in weaners

After weaning (> 6 months) the male and female calves showed different growth pattern. Usually, male weaners grown faster than female. Thus, simulation of body weight increments of male and female weaners were carried out separately.

1. Male weaners

The growth of male weaners were simulated from the age of 7 months to 16 months. Male weaners or bull calves were no longer in the grazing system after they reached the age of 17 months because they were sent to the feedlot for fattening. Thus, the simulation were carried out up to 16 months of age. Parameter values of male weaners (7 to 16 months of grazing age) were :

Initial body weight = 87.0 kg (average weight of Brahman × KK weaners at 7 months old).

Kgn = 0.323 (based on MAFF, 1975)

DMD = 0.45 (mean digestibility value of available herbage under oil palm plantation)

F-value = 0.00846 (based on Dahlan, 1989)

Delt = 1 day (for monthly weight increments, multiply by 30)

2. Female weaners (heifers)

The growth of female weaners were simulated from the age of 7 to 16 months. Heifers were assumed to reach puberty at the age of about 14 months, thus, they usually become pregnant at the age of 17 or 18 months (based on pregnancy diagnosis done on the heifers under this production system). Due to this condition the simulation of heifers growth were done up to 16 months of age.

Parameter values of female weaners :

All values used were similar to the male weaners except F-value = 0.00679 as showed by Dahlan (1989).

Models used are similar to the preweaners for both male and female weaners.

Validation of cows body weight changes based on models of energy utilization and intake

Body weight changes in cows are mainly due to the change in energy requirements during lactation, pregnancy and also compensatory gain after lactation. These complex processes should be included in the simulating process of the cow's body weight changes. For the validation purposes initial body weight of the individual cow need to be specified and also physiological status such as lactation stage and/or pregnancy stages need to be determined.

In this simulation runs, the individual cow's weight changes were initiated from the weight of the cow after parturition. During the 90 days after parturition the cow was assumed not pregnant (due to early postpartum anestrus). Thus, the energy requirement of the cow during this period is mainly for maintenance, activities and lactation.

$$MERlc = MERM + MERL + MERFEED \quad (5)$$

where MERlc is ME required for early lactation stage (less than 90 days after calving). MERM is ME for maintenance (equation MERM = NEM/kn). MERL is ME for lactation (equation MERL = NEL/$k\ell$). MERFEED is ME for eating activities, and it assumed as 0.04 × MEVI. MEVI is ME of ingested food, where it required about 0.04 MJ for every MJ of ingested food for eating activities (Webster, 1980).

During this stage, the lactating cows usually lost weight. Assuming the feed availability is unlimited, the loss of weight is mainly due to low quality feed consumed and higher demand for energy during early lactation period. Thus extra energy is needed to maintain body functions, this condition will lead to tissue mobilization occurring in the animal. Weight loss due to tissue mobilization can be estimated as

$$Kmo = Te \times kt \quad (6)$$

where Kmo is energy (MJ) derived from tissue mobilization.

Te is energy produce by 1kg tissue mobilized, and kt is coefficient for its utilization. MAFF (1975) suggested Te is approximately 20 MJ/kg for body tissue and a coefficient for its utilization of 0.12.

After 90 days postpartum, the cow was assumed to have had conceived and she will be pregnant for about 9 months. The energy requirement during this stage is consisted of :

$$MERplc = MERM + MERL + MERP + MERFEED \quad (7)$$

where MERplc is ME requirement of pregnant and lactating cow. MERP is ME requirement for maintaining pregnancy.

The ME intake (MEVI) of cow can be calculated by equation MEVI = 14.58 × VI × DMD. If MEVI is less than ME required then tissue mobilization will occur. Weight change (WC, kg/day) due to tissue mobilization in cows can be calculated according to equation :

$$WC = (MEVI - MER)/16.4 \quad (8)$$

Changes in body weight of the cow can be simulated as

$$LW_{(i+1)} = LW_i + WC \times 30 \quad (9)$$

where LW_i is initial body weight or the previous weight of the cow, and $LW_{(i+1)}$ is cow's body weight when increment of time occurred (increment = 30 days).

Simulation of weight changes in the cow was carried out for 360 days (about 12 months) postpartum. Three stages were considered :

Stage 1. Day 1 to day 90 (lactating only)

Stage 2. Day 91 to day 200 (pregnant and lactating)

Stage 3. More than 201 days postpartum (pregnant only)

For each simulation runs, initial body weight of the cow was determined. Initial weight used ranges from 195 to 230 kg. Milk yield of KK cow based on Lee and Devendra (1978) were used to predict the daily milk yield of a simulated cow and energy requirement to produce the milk was calculated according to equation : MERL = NEL/$k\ell$.

Parameter values used in simulation of cow's body weight changes after parturition :

PMY = 642 kg/lactation (Potential milk yield, equation MY1 = PMY × 0.35/60 and MY2 = MY1 − MY1/210 × (DL − 60) were used to calculate daily milk yield)

DL = 200 days (length of lactation period in KK cow)

SNF = 95.0 g/kg (solid not-fat for KK cow's milk)

BF = 35.1 g/kg (butter fat content of KK cow's milk)

F-value = 0.0133 (for stage 1)

F-value = 0.0126 (for stage 2)

F-Value = 0.0100 (for stage 3)

WD = 5.5 kg/day (daily walking distance for grazing based on dry matter availability in the field)

$k\ell$ = 0.549 (efficiency with which ME for lactation is converted into net energy of lactation-MAFF, 1975)

q = 0.35 (mean metabolizability value of herbage found under oil palm plantation, q = ME/GE = 6.3/18)

DMD = 0.55 (digestibility of the herbage)

kn = 0.66 (efficiency of ME is used for maintenance-MAFF, 1975).

Simulation

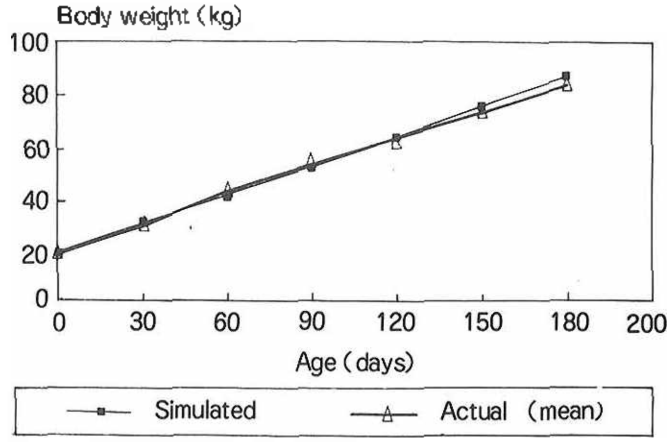
All simulation runs were carried out by using PL/1 programing language in IBM mainframe computer (Underkoffler, 1980). Figure 1 shows example of PL/1 programing for validation of calves growth.

Figure 1. Simulation programme for calves growth.

```
/ * Validation of calves growth in oil palm plantation * /
DCL (FMALE, LWC, DMD)    FIXED DEC (8,5)   INIT (0.0) ;
DCL (VIG, NERG, DGC)     FIXED DEC (8,5)   INIT (0.0) ;
DCL (VI, MEVI)           FIXED DEC (8,5)   INIT (0.0) ;
...
DCL 01 DATA_PT (4) ;
DCL 02 DATA_CALF ;
DCL 03 INLWLAC                   PIC '999V99' ;
  OPEN FILE (INF1),  FILE (INF2) ...
FMALE = 0.00846 ; KG = 0.323 ;
DO J = 1 TO 3 ;
NERG = 0.0 ; DGC = 0.0 ; DGINC = 0.0 ;
IF J = 1 THEN DO ;
DMD = 0.765 ; LWC = 19.5 ;
VIG = FMALE * LWC/(1 - DMD) ;
NERG = 14.6 * KG * VIG * DMD ;
DGC = NERG/(6.28 + 0.0188 * LWC + 0.03 * NERG);
PUT FILE (OUTF)    PAGE EDIT
...
DGINC = DGC * 30 ;
DO K = 1 TO 7 ;
DELT = (K * 30) - 30 ;
IF K = 1 THEN
  LWC_DELT (K) = LWC ;
ELSE
  LWC_DELT (K) = LWC_DELT (K-1) + DGINC ;
PUT FILE (OUTF) SKIP (2) EDIT
END ; END ;
IF J = 2 THEN DO ; ......
```

Results and Discussion

Figure 2 shows the simulated and actual body weight changes of preweaners under oil palm plantation. Four calves (two males and two females) actual body weight data were used to compare with the simulated data. Simulated preweaner weight was in close agreement with the respective actual weights of the calves. The simulated ADG of preweaner was 0.376 kg/day compared with mean of 0.369 kg/day for male and 0.335 kg/day for female calves.

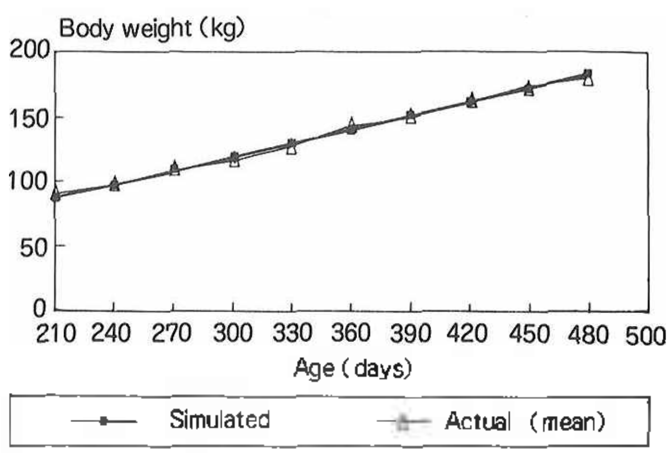


Preweaning age : 0 – 180 days

Actual data collected from PT Plantation

Figure 2. Simulated and actual body weight changes of preweaners.

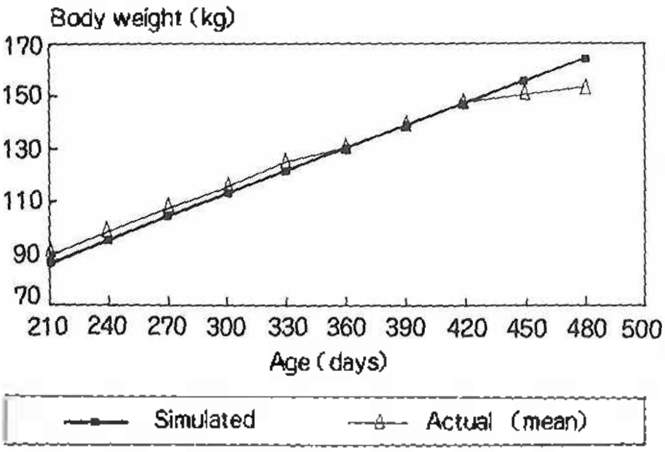
Figure 3 shows the actual growth pattern of male weaners under oil palm plantation compared with the simulated growth. Monthly body weight data from male weaners were used to compare with the simulated data. Figure 4 shows the actual growth patterns of heifers and mean value compared with the simulated growth. The results showed that the simulated growth of male and female weaners are in close agreement with the actual growth of the weaners used for comparison. The simulated ADG of the male weaners was 0.354 kg/day whereas the mean ADG of weaners grazing under oil palm at the age between 7 to 16 months old was 0.337 kg/day.



Weaners age : 210 – 489 days

Actual data collected from PT plantation

Figure 3. Simulated and actual body weight changes of male weaners.

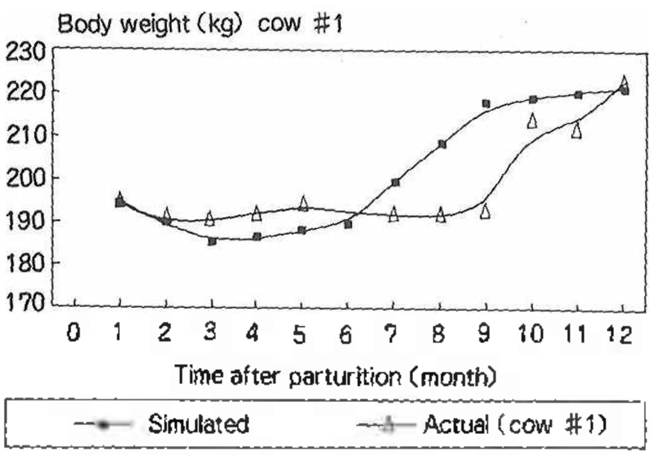


Weaners age : 210 ~ 489 days
Actual data collected from PT plantation

Figure 4. Simulated and actual body weight changes of female weaners.

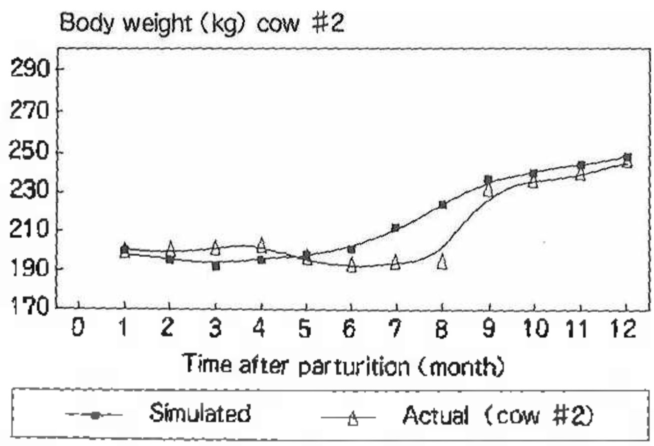
The simulated ADG of female weaners was 0.285 kg/day whereas the mean ADG of grazing female weaners at similar age group was 0.279 kg/day. This result showed that the models used are well fitted to the real conditions of the system.

Figure 5 to 8 show the comparison between actual and simulated body weight changes in cows. The cows used for comparison were based on similar body weight after calving (weight 195, 200, 210, and 230 kg), calving date and also pregnant during 6 to 9 months after calving (usually more than 3 month pregnant). Although there were some variations between simulated body weight and actual body weight found, the simulated cow's weight was in close agreement with the respective actual cow's weight. The variation in the weight could be due to differences in the stages of pregnancy between actual and simulated cow and also the actual calf weaning time or time to dry the cow. In grazing situation the actual weaning age of the calf usually varies and the weaning age of 6 or 7 month old can never be strictly followed by the management. Feed availability for the cows from the plantations also changes in quantity and quality according to seasonal pattern and management practices (Dahlan, et al., 1993) where else simulation runs used average parameter values in the determination of quantity and quality of the feed offered.



Simulation done based on initial body wt of 195 kg and time after parturition.

Figure 5. Simulated and actual weight changes of cow after parturition.



Simulation done based on initial body wt of 195 kg and time after parturition.

Figure 6. Simulated and actual weight changes of cow after parturition.

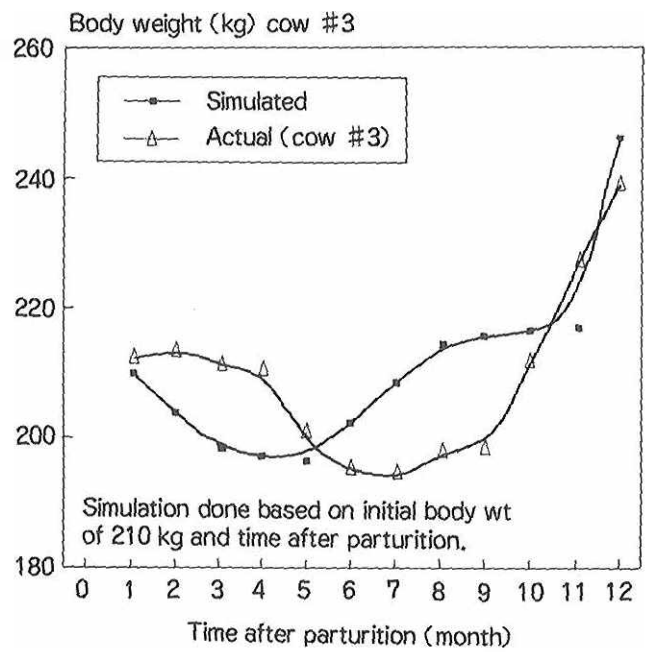
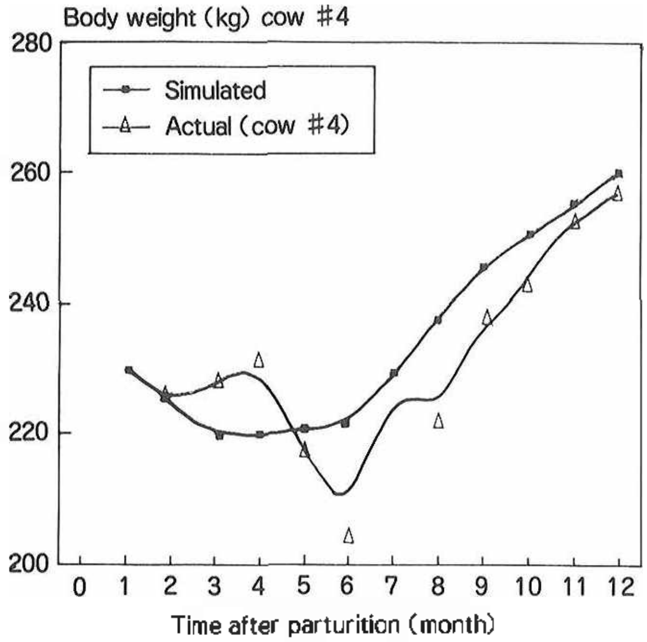


Figure 7. Simulated and actual weight changes of cow after parturition.



Simulation done based on initial body wt of 230 kg and time after parturition.

Figure 8. Simulated and actual weight changes of cow after parturition.

Conclusion

This study showed that the validation demonstrated the degree of agreement between the pattern of actual and simulated data. Thus variation between actual and simulated weight of calves and cows were small and not significant. It was concluded that there was an agreement between the actual and simulated data. Differences at specific points did occur, but the magnitude of differences was small. The variation found between actual and simulated values mainly due to measurement errors and precision during field data collection. More importantly the simulations followed the trends of the actual data of the various physiological stages of animal in the real system.

This indicates that the generalized structure of the grazing cattle energy utilization (EU) model, when coupled with appropriate models of herbage production under oil palm plantation (Dahlan, et al., 1993) enables us to predict the carrying capacity or output of the production system based on given situation of an oil palm plantation system.

Literature Cited

Carson, E. R., C. Cobelli and L. Finkelstein. 1983. The mathematical modeling of metabolic and endocrine systems. John Wiley and sons, New York. p. 394.

Dahlan, I. 1989. Modeling and simulation of herbage and cattle production systems under oil palm plantations in Malaysia. Ph. D dissertation, Kyoto Univ. p. 230.

Dahlan, I., Y. Yamada and M. D. Mahyuddin. 1993. Botanical composition and models of metabolizable energy availability from undergrowth in oil palm plantations for ruminant production. Agroforestry Systems. 24:233-246.

Hillel, D. 1977. Computer simulation of soil-water dynamics. A compedium of recent work. IDRC-082e. p. 214.

Lee, K. C. 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.

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

Underkoffler, M. M. 1980. Introduction to structural programming with PL/1 and PL/C. Prindle, Weber and Schmidt, Boston, Massachusetts. p. 272.

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.