UNDERSTANDING AND PREDICTING DAIRY COW RESPONSES

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Summary

A simulation model is described which allows estimated total energy intake of a dairy cow to be partitioned into allocations for milk production and liveweight change. The basic input data for the model are feed availability and quality. Validation against field data from south-western Australia is presented.

I. INTRODUCTION

As early as 1944, a simple mathematical model of the energy balance in the dairy cow was used to help explain how various factors affect milk production and liveweight change (Brody 1945).

Broster's review in 1958 stated that "the problem now becomes the calibration of the response curve (for milk production), but it is in relation to this aspect of the problem that current knowledge is limited". Today, after 17 years, the situation has not changed. There are more experimental data available, but most research has been focused only on parts of the entire system, usually milk production during lactation (or part thereof) or liveweight changes.

The energy balance equation used to describe the complete system (disregarding protein balance etc.) is:

$$TDE = M + EG + EM + EF \qquad (1)$$

where
TDE = Total digestible energy intake
M = Energy requirement for constant liveweight (maintenance)
EG = Energy requirement for cow growth
EM = Energy requirement for milk production
EF = Energy requirement for foetal growth

The model of a dairy cow system described here enables a simple energy partition for prediction of animal response to management strategy and hopefully can be an avenue for communicating research to the farmer by relating mechanisms back to the observable input components of the model. The model is designed to give the user (farmer or farm adviser) an appreciation of the factors affecting output.

II. SYSTEM COMPONENTS

The components of the system and the factors affecting them have been assessed as follows:

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Component	Factors Affecting
TDE	Live weight (LW) Digestible energy content of pasture (DE), Temperature (T), Pregnancy, Lactation, and Breed.
M	LW, Exercise (related to feed availability), digestibility (related to DE), Temperature (T)
EG	LW, TDE, M, EF, EM
EM	TDE, M, EF, EG
EF	Cow level of nutrition, but mainly a function of stage of pregnancy

(a) Total digestible energy intake

The relationship we have used is: TDE = PC * DE where PC = pasture (feed) consumed, calculated by:

$$PC = 3.75 - .00249 * LW \quad (g/kg)$$

which is derived from the data of Hodgson and Wilkinson (1967). LW is measured in kg and PC in grams. This equation is for a non-lactating non-pregnant animal. PC is adjusted for stage of pregnancy and lactation; the first by using a multiplier of 1.0 to 1.3 over the last three months of pregnancy; the second by using a factor of 1.3 times PC, decreasing at a rate of .03 per month (approximation).

(b) Maintenance energy requirement

This is calculated using equations derived from ARC standards:

i.e. $M = 3.98 + .0176 * LW \quad LW < 390\text{ kg} \quad (M\text{ cal})$
$M = 7.5 + .0088 * LW \quad LW > 390\text{ kg} \quad (M\text{ cal})$

(from tables presented by Rickards and Passmore 1971).

M is then adjusted for an exercise factor based on pasture and supplementary feed availability, and also for the average digestibility.

(c) Energy requirement for a developing foetus

It has been assumed that the value of EF does not often influence lactation, and becomes important only during late lactation.

In order to solve equation 1 for EM and EG a new concept must be derived.

(d) Identification of unknown variable

There are many reports on the influence of feeding immediately pre-calving (steaming up), on the subsequent lactation. Therefore some component, presumably M or EG, in equation (1) must be influenced. As M is mainly dependent on LW, digestibility, and exercise at a given time (Rickards and Passmore 1971), EG must be related to some unidentified variable pre-set during "steaming up".

The variables M, EG, EM and EF can be grouped into those relating to the mother, and those relating to a calf (milk), or a foetus. We assume a partioning of energy intake:

$$TDE = E_{(cow)} + E_{(calf)}$$

where;

$$E_{(cow)} = EG + M \quad \text{and} \quad E_{(calf)} = EM + EF$$

Detailed study of many cow live weight patterns showed that almost all cows had a common pattern of liveweight change. Soon after calving, the live weight of all animals dropped to 80% of the pre-calving live weight (Table 1). They also tended to revert to that live weight after any variation in feeding strategy had caused a change.

TABLE 1

The relationship of post-partum liveweight (1 month) to pre-partum liveweight (B) for various management strategies applied to dairy and beef cows in different localities

Location	Stocking rate	Time of calving	B (%)	No. of cows	Range (%)
Wongan Hills†	Low	Early	80.6	16	75-85
	High	Early	78.7	19	76-82
Denmark*	Low	Early	79.9	14	76-82
	High	Early	78.7	12	74-83
	Low	Late	82.9	14	80-85
	High	Late	81.4	14	77-85

* Herds were mixed Friesian and Guernsey

† Hereford cows

Changes in live weight were closely correlated with seasonal feed availability even when the quality of the feed was decreasing. From the two part maintenance energy concept of Smith (1970) of a basal maintenance requirement for tissue life and an additional component for exercise, it is assumed that weight loss or gain is related to the energy required for exercise associated with feeding, relative to some pre-set standard. This indicates that prior to calving, the proportion of energy allocated to the cow is set at the maintenance requirement for the post-calving live weight (80% pre-calving LW) under the then existing conditions of feeding (M_{80}). Such that:

$$E_{(cow)} = M + EG \qquad (2)$$

for the energy allocation throughout the lactation.

From equation (2); during lactation, the energy for growth is dependent on the maintenance requirement, and will be positive or negative as M varies about $E_{(cow)}$. In the model, $E_{(cow)}$ is set at M_{80}.

Equation (1) may now be written as:

$$TDE = E_{(cow)} + EM + EF, \text{ or, temporarily ignoring EF, } TDE = E_{(cow)} + EM$$

As $E_{(cow)}$ is controlled for the entire lactation, the live weight will tend towards 80% pre-parturition live weight after any feed variation has caused LW to fluctuate. Milk yield is related to $E_{(cow)}$, and the feed intake capacity of the breed of cow under study.

A computer program of the model was tested against real world situations and the consequences of feed management strategies observed.

III. EXPERIMENTAL

A trial was conducted in the south-west of Western Australia using a rotationally grazing Friesian milking herd. Milk production, live weight, pasture availability (limited) were measured. The pasture availability was used to run the model and the output compared with the field records as a validation comparison.

The comparison is shown in figure 1. The agreement of predicted and measuredvalues from this limited validation is sufficient to suggest the model gives good predictions.

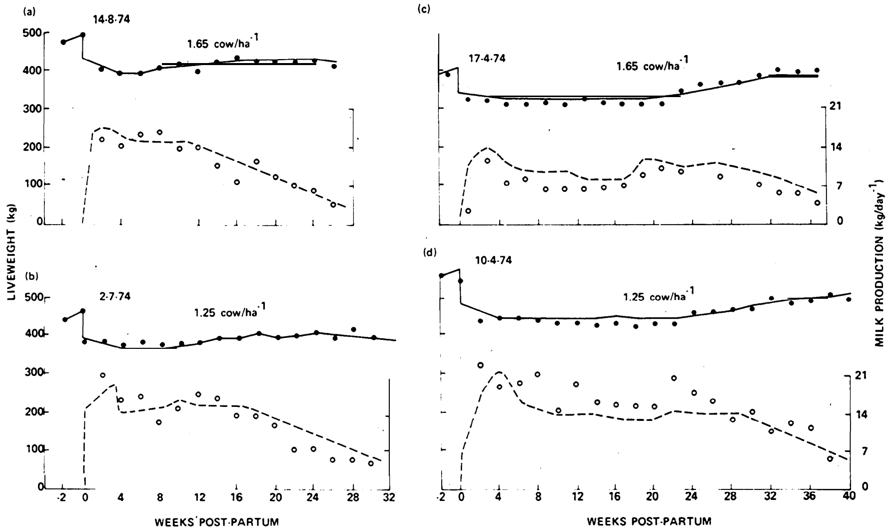

Fig. 1. A comparison of model output of liveweight (——) and milk production (----) calculated from field pasture measurements with recorded field measurements of live weight (●) and milk production (O) for individual dairy cows: (a) grazed at 1.65 cows/ha calving in August; (b) grazed at 1.25 cows/ha calving in July; (c) grazed at 1.65 cows/ha calving in April; (d) grazed at 1.25 cows/ha calving in April. Hay was fed for varying periods on all treatments.

IV. USE OF THE MODEL

The model will be used initially to propose specific experiments designed to query individual sub-systems in the model. At a later stage it may be used to advise dairy managers on management strategies.

VI. REFERENCES

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