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Liveweight, feed intake and feed conversion efficiency of lactating dairy cows

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ABSTRACT

Liveweight, milk yield and feed intake were measured in two experiments, the first with 30 cows grazing on pasture and the second with 16 cows fed indoors on fresh pasture. Feed intakes by the grazing cows were estimated from faecal outputs, using chromic oxide as the indigestible marker. The relation between daily metabolisable energy intake (MEI), daily milk energy output, liveweight$^{0.75}$ ($LW^{0.75}$) and daily change in liveweight were examined by multiple regression analysis.

Milk energy was significantly related to MEI in all analyses, and $LW^{0.75}$ was significantly related to MEI in the majority of the analyses. The partial regression coefficients for $LW^{0.75}$ ranged from 0.8 to 1.4, higher than are commonly reported. The data suggest that an increase of 100 kg liveweight (between 350 and 550 kg) is associated with an increased energy requirement of about 15 MJ ME per day.

The results show that $LW^{0.75}$ has a significant effect on MEI, and therefore (at a common milk energy output) on feed conversion efficiency. An "index of efficiency" is proposed which will enable cows which differ in milk yield, weight and breed to be ranked according to their predicted "gross feed conversion efficiency".

Keywords: Liveweight, lactating cows, feed conversion efficiency, ranking index.

INTRODUCTION

The profitability of New Zealand dairy farms is closely related to their productivity per hectare (Deane, 1993). Feed conversion efficiency (FCE) by the cows is one of the factors which determines the farms productivity per hectare, and its importance has been recognised for many years (Wallace, 1956).

New Zealand's herd improvement programme has been based on selection for yield of milkfat (and more recently for protein also) with the assumption that increased yield per cow is closely correlated with increased FCE (NZDB, 1958). This assumption has been verified by recent studies with cows of high or low genetic merit (Grainger *et al.*, 1985; Bryant, 1981).

However, differences in liveweight can also be expected to have significant effects on FCE; for example, using commonly accepted energy requirements (Holmes *et al.*, 1981) it can be calculated that:

- at a common liveweight, a 25% increase in milksolids yield causes efficiency to improve by 10 to 15%
- at a common milksolid yield, a 25% decrease in liveweight causes efficiency to improve by 10 to 12%.

Nevertheless, the effect of differences in liveweight on FCE, although recognised for many years (eg NZDB, 1958; Wallace, 1956), have not yet been included in the herd improvement programme for ranking of cows within herds. This is likely to lead to the "efficiency" of heavy cows being overestimated relative to the "efficiency" of lighter cows in the same herd. (The effects of differences in liveweight are now included in the index used for selection of sires.)

The present experiment was intended to measure the feed intake and FCE of cows which were similar in milk yield but which differed widely in liveweight, with the cows grazing on pasture and fed indoors on freshy-cut pasture.

MATERIALS AND METHODS

Two experiments were carried out in November and December 1991 at the Dairy Cattle Research Unit, Massey University, using cows, 4 years and older, which were widely different in liveweight but similar in yield of milkfat (Table 1). The majority of cows were Friesian/Holstein with some Jerseys included, but the experiment was not designed to compare the two breeds.

The grazing experiment was carried out for 25 days with 30 cows, separated into 3 groups based on the weights of individual cows. Each group was given a daily pasture allowance equivalent to 2.5 times its calculated feed energy requirement for maintenance and milk production, an arrangement designed to minimise any grazing competition between cows of different sizes (weights).

Milk yield and composition for each cow was measured on 3 days per week, using Metatron Milk Meters (Westfalia Limited) and a Milkoscan analyser (Anfoss, Denmark). The total energy in the daily milk yield of each cow (MJ/cow daily) was calculated as:

$(38.5 \times F) + (24.5 \times P) + (15.7 \times L)$,

where F, P and L are the daily yields (kg/day) of fat, protein and lactose.

Each cow was weighed after the morning milking on two days each week (Tru Test, Ag 500). In addition, the body

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TABLE 1: Descriptions of the cows; mean values measured during the two experimental periods (± SD).

	Grazing experiment		Indoor experiment	
	Friesian Holstein	Jersey	Friesian Holstein	Jersey
Number of cows	22	8	11	5
Age (years)	6.0 (± 1.0)	5.5 (± 1.2)	6.2 (± 1.1)	5.0 (± 1.3)
Milk energy (MJ/day)	80 (± 9.8)	74 (± 6.9)	65 (± 7.6)	61 (± 8.8)
Milkfat (kg/day)	1.05 (± 0.09)	1.04 (± 0.11)	0.88 (± 0.11)	0.87 (± 0.11)
Milk protein (kg/day)	0.83 (± 0.09)	0.73 (± 0.10)	0.67 (± 0.08)	0.62 (± 0.09)
Liveweight (kg)	463 (± 51)	350 (± 34)	498 (± 55)	371 (± 33)
Overall mean liveweight (kg)	436 (± 69)		458 (± 76)	
Feed intake (kg DM/day)	18.1	15.6	18.0	14.9

condition score of each cow was assessed on two days at the start and again at the end of the experimental period.

Faecal output by the grazing cows was estimated using chromium as an indigestible marker. Daily pasture intake was then calculated from the digestibility of pasture apparently eaten by the cows and their daily faecal output (Parker *et al.*, 1989).

During the first half of the grazing experiment (Period 1), chromium was given via 2 gelatin capsules per cow daily (10 g chromium per capsule; R.P. Sherer Pty Limited), and during the second part (Period 2) it was given via a slow release ruminal capsule (Captec New Zealand Limited).

Faeces were collected in the paddock, twice daily (07.00 and 14.00) over 10 days in Period 1, and once daily (14.00) over 8 days in Period 2, after 6 days for equilibration in each case. The concentration of chromium was measured as described by Parker *et al.* (1989). During these periods samples of pasture were cut at grazing height from within exclusion cages and digestibility was measured *in vitro* (Roughan & Holland, 1977). Daily feed intake was then calculated as described by Parker *et al.* (1989). Daily intake of metabolisable energy (MEI) was then calculated, assuming a value of 15.6 MJ ME/kg DOM (Geenty and Rattray, 1987).

The values for intake used in this report are from Period 1, when data were available from all 30 cows. In period 2, data were available only for 16 Friesians and 8 Jerseys, because the faeces from the 6 heaviest Friesians contained very low concentrations of chromium, presumably because the capsules had been lost from these cows.

The indoor experiment was carried out for 18 days with 16 cows housed in individual stalls in the feeding barn, and given freshly-cut pasture twice daily in quantities sufficient to ensure that approximately 10% was refused each day. Dry matter concentrations of the fresh herbage, and in the refusals from each cow were measured each day.

Milk yield and composition, and liveweight were measured as for the grazing experiment; milk energy was calculated as shown above.

Pasture intake was measured directly, as the difference between the weight of pasture DM offered each day and the weight of pasture DM left uneaten (refusals) at the end of 24 hours. The digestibility of the herbage offered was measured *in vitro*, and the metabolisable energy concentration calculated as shown above.

Analysis of data

The data was subjected to multiple regression analyses according to the model:

MEI (MJ per cow daily) = a x Milk energy (MJ per cow daily) + b x $LW^{0.75}$ (kg) + c x LW change (kg)

either constrained to give a value of zero for the regression constant (Intercept = 0),

or unconstrained, with the regression constant included.

RESULTS

The mean values for liveweight and yields of milksolids and energy by the cow in both experiments are shown in Table 1.

Some results of the multiple regression analyses are shown in Table 2, for the two forms of analysis ((a) with no regression constant, and (b) with regression constant) and for the indoors and outdoor experiments. The data for the Friesians has been analysed alone, and in combination with the data for the Jerseys. The data for the Jerseys were not analysed separately, because of the small number of Jerseys. Data for Period 2 of the grazing experiment have not been presented because the loss of data for faecal output from 6 of the heaviest Friesians caused the range of liveweight between cows to decrease considerably, and reduced the significance of all the partial regression coefficients.

In all regressions, the coefficient for milk energy (MJ ME eaten/MJ milk energy produced) was statistically significant, ranging from 1.55 to 1.98 indoors, and from 0.83 to 1.10 grazing.

The coefficient for $LW^{0.75}$ was statistically significant in all but one equation (for the 11 Friesians indoors) ranging from 0.61 to 1.00 indoors, and from 1.20 to 1.38 grazing (with units of MJ ME eaten per $kg^{0.75}$, daily).

A number of points should be noted about the data and the partial regression coefficients (Table 2):

- in theory the regression coefficient for milk energy cannot be less than 1, unless the partial efficiency of milk synthesis is greater than 100%, which is impossible.
- the two independent variables, LW and milk energy, were slightly intercorrelated ($P < 0.10$) for the grazing experiment, but not for the indoor experiment.
- Age was correlated with LW in both experiments (0.59 and 0.46; $P < 0.01$). However, inclusion of age in the multiple regression analyses did not remove the significant effects of $LW^{0.75}$ on MEI shown in Table 2, although age was significantly related to MEI ($P < 0.01$) for the grazing experiment.

In order to illustrate the relation between $LW^{0.75}$ and ME Intake for all cows, the data for individual cows were adjusted to the common yield of milk energy using the appropriate

TABLE 2: Results of multiple regression analyses (± SE) to show the relationship between milk yield (total energy), liveweight$^{0.75}$ and change in liveweight (units shown in Table) and the quantity of metabolisable energy eaten (MJ ME/cow daily).

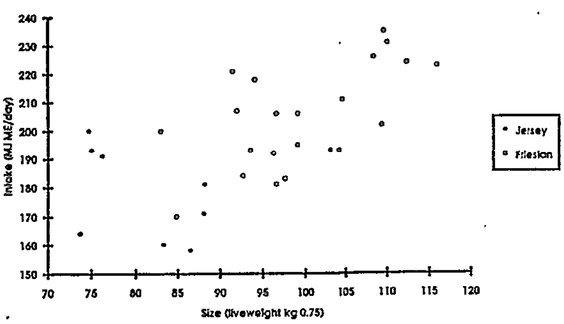
Source of data	Regression constant (Intercept)	Partial regression coefficients for: Milk energy (MJ/day)	Liveweight ($kg^{0.75}$)	Liveweight change (kg/day)	Value for R^2
(a) Constrained to zero regression constant					
Friesians					
Grazing (22 cows)	-	0.99 ** (± 0.27)	1.20 ** (± 0.22)	13.3 NS	0.99
Indoors (11 cows)	-	1.98 ** (± 0.27)	0.61 ** (± 0.17)	1.84 NS	0.99
Friesians and Jerseys					
Grazing (30 cows)	-	0.88 ** (± 0.27)	1.27 ** (± 0.23)	14.0 NS	0.99
Indoors (16 cows)	-	1.55 ** (± 0.26)	0.84 ** (± 0.17)	2.8 NS	0.99
(b) Regression constant included					
Friesians					
Grazing (22 cows)	29.5 NS	1.10 ** (± 0.33)	1.38 ** (± 0.34)	17.5 NS	0.58
Indoors (11 cows)	44.1 NS	1.75 ** (± 0.36)	0.34 NS (± 0.33)	0.4 NS	0.78
Friesians and Jerseys					
Grazing (30 cows)	11.2 NS	0.83 ** (± 0.34)	1.20 ** (± 0.28)	11.2 NS	0.57
Indoors (16 cows)	16.4 NS	1.55 ** (± 0.35)	1.00 ** (± 0.22)	7.27 NS	0.80

(NS = Not significant; * Significant at $P < 0.05$; ** Significant at $P < 0.01$.)

regression coefficients in Table 2 (0.88 for grazing cows and 1.55 for indoors cows).

These adjusted data are presented in Figures 1 and 2, which show that despite the relatively wide scatter of the individual data, the significant effect of $LW^{0.75}$ is clear. They also suggest that the data for Jerseys and Friesians appear to lie approximately on a common regression line.

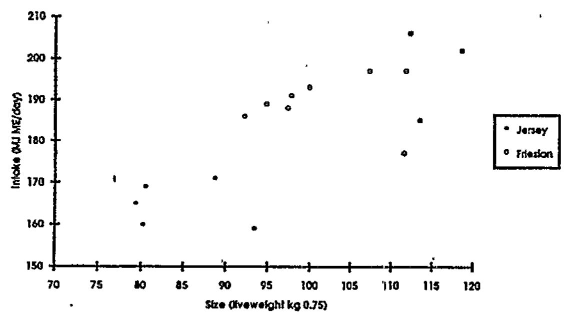
FIGURE 1: Grazing Experiment: Relation between livewight and feed intake, after adjustment to the mean value for milk energy (78 MJ/day).



The data in Figures 1 and 2 do not take account of between cow variation in liveweight gain, because even though this variation probably did have a small effect on ME intake, its effects were not significant.

The data in Figure 1 were used (by simple regression) to estimate daily dry matter intakes by cows of different weights, and their feed conversion efficiencies (kg protein/tonne DM eaten) were then calculated. The results are shown in Table

FIGURE 2: Indoor Experiment: Relation between liveweight and feed intake, after adjustment to the mean value for milk energy (64 MJ/day).



3. These show that, at a common milk yield, a decrease in LW of about 25% is associated with an increase in efficiency of about 12%; this is similar to the effects predicted from currently accepted feeding standards (see the introduction).

DISCUSSION

Effects of LW and milk energy on feed intake

The results show that differences in $LW^{0.75}$ and in milk energy both accounted for significant proportions of the total variability in MEI for these cows. The present values for the regression coefficient for $LW^{0.75}$ (with units of MJ ME/$kg^{0.75}$), were 0.6 to 1.0 indoors and 1.2 to 1.4 grazing. These are generally higher than corresponding estimates for maintenance requirements from calorimetric experiments (0.5 to 0.6; Holmes *et al.*, 1981) and calculated from indoor and

TABLE 3: Values for feed intake taken from Figure 1, and calculated values for feed conversion efficiencies for cows of different weights but all producing 78 MJ milk energy/day*.

Liveweight (kg)	Feed intake (kg DM/day)	Feed conversion efficiency (kg protein/tonne DM eaten)
350	16.5	49
450	18.5	44
550	20.0	41

(*Approximately equivalent to:
Friesian milk : 22.8 litres; 1.05 kg fat; 0.82 kg protein
Jersey milk : 19.6 litres; 1.12 kg fat; 0.79 kg protein)

outdoor grazing experiments (0.7 to 1.1; Hutton, 1962; Wallace, 1956 and 1961; Curran & Holmes, 1970).

However, the present regression coefficients for $LW^{0.75}$ must be interpreted with caution for a number of reasons:

- the correlations between LW and milk energy, and between LW and age noted in the results, is not compatible with the ideal requirement that the independent variables in multiple regression should not be intercorrelated.
- for the grazing cows, the relatively high values for the regression coefficient for $LW^{0.75}$ (eg 1.20 and 1.27) were associated with relatively low values for the regression coefficient for milk energy (0.99 and 0.88). These latter values imply that the partial efficiency for the synthesis of milk from MEI is greater than 100%, which is impossible. The expected values for the regression coefficient for milk energy are about 1.5 (65% efficiency) similar to that calculated indoors for all cows, which was associated with lower values for the regression coefficient for $LW^{0.75}$ (0.84 and 1.00).

These and other problems of interpretation were discussed fully by Curran & Holmes (1970).

Despite all of these reservations, the present data can be used to provide credible estimates of maintenance requirements for cows fed indoors on fresh forage of between 0.8 to 1.0 MJ ME/$kg^{0.75}$ daily. These, taken in conjunction with the older data of Hutton (1961) and Wallace (1961), more recent recommendations for grazing cows (CSIRO, 1990), plus the report by Stakelum & Connolly, (1987) that the actual pasture intake by stall-fed cows was considerably higher than would have been predicted by the ARC (1980) requirements, suggest that the maintenance requirement of cows fed on pasture, and in particular grazing cows, are higher than the conventionally accepted value of about 0.6 MJ ME/$kg^{0.75}$.

Effects of LW on feed intake and conversion efficiency

The present data show that increases in LW are associated with increases in feed intake, and at a common milk yield, decreases in conversion efficiency. Similar effects of phenotypic differences in LW have been reported by several authors (Hutton, 1961; Wallace, 1961; Curran & Holmes, 1970; Stakelum & Connolly, 1987). There appears to be only one reported study of the effects of genetic differences in LW (Yerex *et al.*, 1988), which showed that after 3 generations LW had been reduced by 10% to 450 kg, in association with an increase of 5% in feed conversion efficiency.

There is no doubt that LW does influence feed requirements, and that a reduction in LW, with milk yield held constant, will cause an increase in efficiency. However, there is still considerable uncertainty about the actual value which should be used for the maintenance requirement for grazing cows.

In this context, it is reassuring to find that a large difference in the assumed value for maintenance has relatively small effects on the calculated **differences** in efficiency between big and small cows. For example, if a value of 0.6 MJ ME/$kg^{0.75}$ daily is assumed, then a 350 kg cow is 19% more efficient than a 550 kg cow if both produce 160 kg milkfat per year. The corresponding difference is 26% if a value of 1.2 MJ ME/$kg^{0.75}$ daily is assumed.

Relative effects of LW and milk yield

Feed conversion efficiency is increased by approximately the same amount by:
either - an increase in milk yield of 10%,
or - a decrease in liveweight of 10%.

However, a decrease in LW causes the increase in efficiency only by reducing the energetic cost of maintenance per kg milk, and it will probably reduce the income from meat. Whereas an increase in milk yield not only causes a decrease in the energetic cost of maintenance per kg milk (by "dilution of maintenance"), but also a decrease in some of the economic costs per kg milk. These factors, and others, have been combined into the Livestock Improvement Corporation's Total Breeding Index for bulls (LIC, 1991).

CONCLUSIONS

Dairy farm productivity per hectare, and hence profitability, are affected by the cows' feed conversion efficiency, which is affected not only by their yield of milksolids but also by their liveweight.

Therefore, a "feed conversion efficiency index" is required to rank cows within and across herds. This index could be in the form of:

$$\frac{\text{Yield of Milk energy (M*)}}{(M \times 1.5) + (LW^{0.75} \times 0.8)}$$

(where the bottom line is an approximate estimate of the cows total energy requirement.)

This index is effectively a measure of the yield of milk energy per MJ ME eaten, and it could be applied with reasonable confidence across breeds, using data currently recorded by the herd testing service, plus information about the LW of each cow.

(* M can be estimated from yield of milk, and the concentration of fat and protein, Tyrrell & Reid, 1965.)

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