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Comparing feed allowances to inferred energy intake using data from a dairy grazing farm trial

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ABSTRACT

The main objective of this research was to investigate whether calculating intake of dairy cows using equations to predict energy requirements provides a good alternative to conventional ways of estimating intake. The method was applied to data from the Dexcel Holstein-Friesian strain trial over three seasons. Feed intake per cow was calculated as the sum of the energy requirements for maintenance, milk production, pregnancy, growth and body tissue mobilisation using measured yields of milk, fat, protein and lactose, live weight and body condition score of cows and calf live weights. In order to compare the estimates of feed intake to the amount of feed offered, linear regressions of calculated (ME) intake (grouped by farmlet) on the amount ME offered per farmlet were performed by season. The relationship between ME intake and ME offered was weak in the first year, with a limited response to increasing the amount of feed offered. This was because all the cows were two-year-olds with lower live weights and milk yields and consequently lower feed intakes. In the subsequent two years of the trial, the relationship between ME intake calculated using the energy equations were 67% and 72%. The modern strains of dairy cows responded well to higher levels of feed offered, while the 1970s strain of New Zealand dairy cows failed to increase intake when offered diets of higher total ME. Our results show that energy prediction equations offer a viable and cheap alternative of estimating ME intake of lactating dairy cows.

Keywords: dairy cows; energy intake; strain comparison; efficiency.

INTRODUCTION

Many farmlet grazing trials are designed to test the effects of different feed allowances on animals. The amount actually eaten always differs from what is offered, depending on the weather, digestibility and metabolisable energy content of feed, feed wastage and cow appetite, etc.

Common ways in which feed intake at pasture is determined include the use of a rising plate meter to quantify pre- and post-grazing herbage masses, but the main limitation with this approach is that feed intakes are for groups of animals, rather than individuals. Alkane markers allow feed intakes to be measured for individual animals. However, intake measurements determined through alkanes are often reported to be inaccurate (Waghorn *et al*., 2004), are expensive and time-consuming and are usually only measured over short periods of time. Both methods are affected by the pasture composition and the digestibility and metabolisable energy content of feed.

Predicting feed intake through easy-to-measure characteristics of cows is one way in which feed intake can be assessed over longer periods for individual cows. In the present study, equations to predict energy requirements for maintenance, milk production, pregnancy, growth and body condition score (BCS) change (mainly from AFRC, 1993) but with some adaptations were used to calculate energy intake on a per cow basis using data from the Dexcel Holstein-Friesian Strain Trial. The estimated values for energy intake can be used to compare feed intake of groups of animals with the amount of feed offered and intakes estimated using pre- and post-grazing masses. Additionally, as shown in Pryce *et al.* (2005), it can also be used to apportion feed costs derived for groups of animals between members of the farmlet, according to the relative estimated feed demands, or to calculate traits such as the proportion of energy partitioned to milk production, which is a measure of dairy cow efficiency.

The objectives of this research were 1) to investigate whether calculating ME intake of individual cows using equations to predict energy requirements provides a good alternative to conventional ways to estimate feed intake of dairy cows; 2) use the ME intake estimates to investigate differences between strains and feeding levels in the proportion of energy partitioned to milk production.

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MATERIALS AND METHODS

Data

Data were from the Dexcel Holstein-Friesian Strain trial over three seasons: 2001/2002 to 2003/2004. Details of the strains and experiment are described by Harris *et al.* (2003), Rossi *et al.* (2004) and Macdonald *et al.* (2005). In brief, there were three strains of cows (New Zealand 1990's strain: NZ90s; overseas 1990's strain: OS90s and New Zealand 1970's strain: NZ70s) managed as eleven farmlets in groups of 20 cows (for NZ90s and OS90s strains, with four farmlets per strain) and groups of 15 cows (for NZ70s strain, with three farmlets).

Feed allowances were manipulated by altering both stocking rate and the availability of supplementary feed and total feed allowances per cow ranged between 4.5 to 7.0 t DM/cow/year. The supplementary feed was predominantly maize silage and maize grain. Five of the eleven farmlets had no supplementary feeding.

The ME intake per cow per year was calculated as the sum of annual energy requirements for maintenance and activity, pregnancy and milk production. Energy requirements for maintenance and activity (*MEmaint*) as defined in Equation 1 were estimated using lactation average live weight (LWT) and is an adapted version of the equation proposed by AFRC, (1993), while energy requirements for milk production requirements (*MEmilk*) were calculated using total milk fat (fat), protein (prot), lactose (lact) and milk volume (vol) yields (Tyrell & Reid, 1965 in AFRC, 1993; Equation 2). Pregnancy requirements (*MEpreg*) were calculated using the AFRC (1993) equations, actual calf birth weights (calfLWT) (Equation 3). The equation to predict the body content of fat (BCF) from change in BCS based on an assumed empty body weight (EBW) of 0.8117 of lactation average live weight (Gregory *et al.,* 1998) (Equation 4) was used as the basis of the calculation of energy supplied or required from BCS change in addition to the principles of BCS change from the NRC (2001) this is presented in Equation 5 (*MEbcs*). The difference in BCS from end of lactation to target BCS at calving (5) was used, this difference was assumed to represent the amount of BCS that needs to be recovered during the dry period. Energy requirements for growth (*MEgrowth*) were estimated using the AFRC (1993) method (Equation 6), using increases in live weight from the start of lactation to the end of lactation, net of live weight associated with BCS increase.

Equation 1:

$$MEmaint = \frac{365\left(0.53\left(\frac{LWT}{1.08}\right)^{0.67} + 0.019 * LWT\right)}{k_m}$$

Equation 2:

$$MEmilk = \frac{38.4Fat + 22.3\,\mathrm{Pr}\,ot + 19.9Lact - 0.108Vol}{k_l}$$

Equation 3:

$$MEpreg = \frac{\left(\frac{10^{151.665-151.64*e^{(-0.0000576*282)}}}{k_p}\right)}{36.2}calfLWT$$

Equation 4:

$$BCF = \frac{(-1.1043 + 1.7541 \times BCS)}{100} \times EBW$$

Equation 5:

$$MEbcs = \frac{(BCF_{t+1} - BCF_t) \times Efat}{k_g}$$

Equation 6:

$$MEgrowth\frac{(LWT_{t+1} - LWT_t) \times 19}{k_g} - MEbcs$$

Where *t* is time, k_m is the efficiency of utilisation of energy for maintenance, k_l is the efficiency of utilisation of energy for lactation and k_p is the efficiency of energy for pregnancy and k_g is the efficiency of energy used for growth assumed to be 0.678, 0.6, 0.13 and 0.55 for k_m, k_l, k_p and k_g respectively. The efficiencies were assumed to be the same for each group of animals (farmlets) as there was no evidence to suggest otherwise. The heat of combustion for body fat (*Efat*) at various stages of lactation has been suggested to be 39.33 MJ/kg (NRC, 2001).

Feed offered was compared to calculated feed intakes grouped by farmlet. ME offered was calculated using ME values of components of the diet by farmlet and within season and values of tDM offered. The relationship was investigated using a linear regression of the average ME intakes per farmlet on ME offered by season in JMP (SAS, 2004).

A measure of dairy cow efficiency is the proportion of energy partitioned to milk production this was calculated as:

Equation 7:

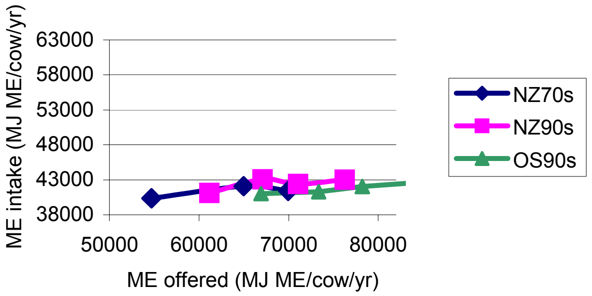
$$Efficiency = \frac{MEmilk}{MEma\,\mathrm{int} + MEmilk + MEpreg + MEbcs + MEgrowth}$$

In addition to calculating energy requirements using these equations, ME intakes were calculated from pre- and post- grazing masses and recorded amounts of pasture and maize silage and maize grain fed to the animals.

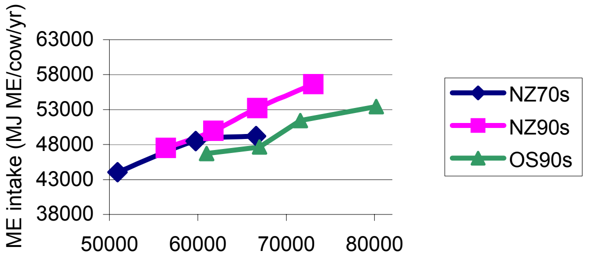
RESULTS

FIGURE 1: The relationship between ME intake per cow calculated using Equations 1 to 6 and feed offered per cow (MJ ME/cow/year)

a) 2001



b) 2002



c) 2003

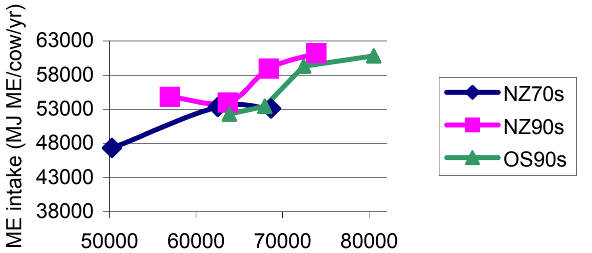
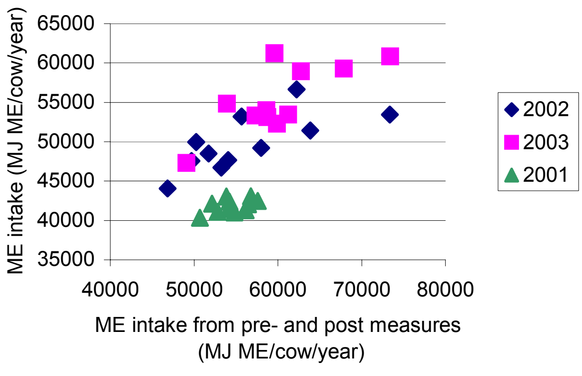


Figure 1 shows the relationship between the calculated ME intake and ME offered for each of the three seasons of the trial. The regression of ME intake on ME offered was calculated and values for the R-squared for each relationship were 51%, 62% and 67% for 2001, 2002 and 2003 respectively. Estimated pasture utilisation (ME intake/ME offered) in 2001 varied between 74% for the NZ70s strain offered 4.5 tDM/cow to 51% for the OS90s strain offered 7 tDM/cow. The same trend was seen in 2002 with better rates of pasture utilisation at lower levels of feed offered. In 2003, estimated pasture utilisation varied between 96% for the NZ90s strain offered 5 tDM/cow to 76% for the OS90s strain offered 7 tDM/cow.

FIGURE 2: The relationship between ME intake calculated using Equations 1 to 6 and feed intake calculated using pre- and post-grazing masses and supplements fed, each point represents the mean ME intake of a farmlet



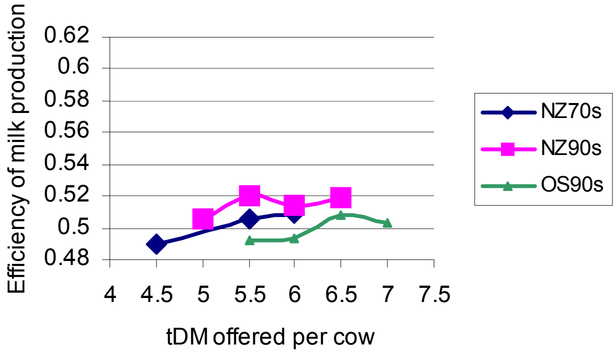
ME intake was also calculated using pre- and post-grazing masses plus supplements fed. ME intake calculated using Equations 1-6 versus ME intake calculated from data collected is shown in Figure 2. The correlations between ME intake calculated in these two ways varied between 0.51 in 2001 and 0.77 in 2003. Within strain (across all three seasons), the correlations were 0.74 for NZ90s, 0.64 for OS90s and 0.63 for NZ70s. The correlation was weakened by the poor relationship between the intake measurements in 2001. In 2003, the relationship between the two intake measurements was 0.97 for the NZ90s strain, as this correlation is within strain and based on four data points, it should be treated cautiously.

The relationship between feed offered and proportion of energy partitioned to milk production is shown in Figure 3. The NZ70s partitioned most energy to milk production at 5.5 t DM offered in 2002, but generally the trend in all three strains was increasing in allocating energy to milk production with increasing in amount of feed offered. The means of the three strains adjusted for feeding level, parity and season (with standard errors in brackets) were statistically different ($P < 0.001$) and were: 0.559 (0.003), 0.529 (0.005) and 0.536 (0.004) for NZ90s, NZ70s and OS90s respectively.

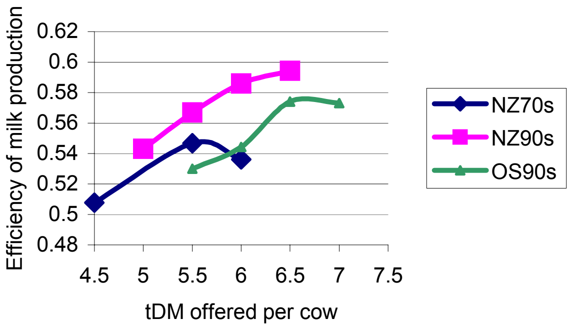
As long as growth and changes in BCS are properly accounted for, the energy requirements for maintenance and pregnancy should remain almost constant (within strain) as feeding level increases, apart from requirements related to increases in body size

FIGURE 3:. The relationship between the proportion of energy partitioned to milk production (efficiency; Equation 7) versus feed offered per cow (tonnes of dry matter, tDM)

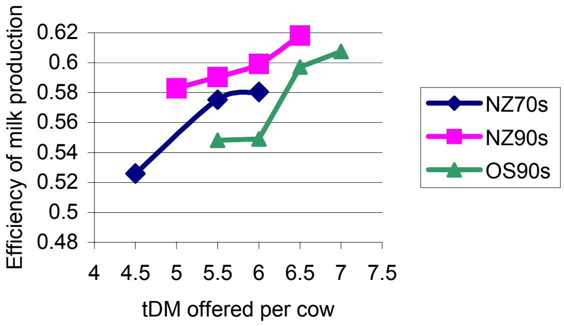
a) 2001



b) 2002



c) 2003



associated with higher feeding levels. Across all three seasons, the effect of feeding level (nested within strain) was not significant for maintenance and pregnancy requirements for the NZ70s and OS90s strains. For the NZ90s strain, there were no significant differences between feeding levels in 2001, but in 2002 and 2003 ME requirements for maintenance and pregnancy increased significantly with feeding level.

DISCUSSION

The energy requirements calculated from Equations 1-6, showed that requirements for milk production were greatest (48% to 61%), followed by maintenance requirements (35% to 44%). Energy required for pregnancy, growth and BCS change accounted for between 5% and 10% of total energy requirements. The method for deriving energetic requirements arising from BCS change presented here is a prototype and remains under review, its contribution to total energy was small (0% to 1.3%) and so the impact on the results presented here is likely to be negligible.

The relationship between calculated ME intake and ME offered was weak in the first year, because the trial herds were all two-year-olds and mean yields and live weight were lower than in the subsequent two years of the trial. So, in 2001 the feed offered to each farmlet was more than the cows were able to eat. The R^2 of feed intake to feed offered was 38% in 2001 and 67% and 72% in 2002 and 2003 respectively and is comparable to other studies. For example, Penno (2001) compared ME intake calculated using alkanes to ME allowance in four periods of the year each of 35 days. Where ME intake of pasture was determined using pre- and post-grazing mass, plus individual intakes of supplementary feed. In Penno's study, the R^2 of the relationship between ME intake and ME allowance varied between 67% (winter) to 85% (spring). In the present study, the relationship between ME intake calculated using pre- and post-grazing masses plus supplements and ME offered had an R^2 ranging between 64% (2001) and 90% (2003), which were about 20% higher than the estimates obtained using the energy prediction equations. However, as it is only possible to estimate feed intakes for groups of animals using pre- and post-grazing masses, ME intake calculated for individual cows using the equations 1 to 6 can be useful.

The relationship between ME intake and ME allowance was assumed to be linear within strain in the present study, although over broad feeding ranges a curvilinear relationship between intake and allowance has been reported (Dalley *et al.,* 1999).

One of the limitations in using energy prediction equations to calculate intake is that direct information on feed quality is not used explicitly. It is only used implicitly through indirect effects on both milk yield and changes in BCS and live weight. Another limitation is that the equations and corresponding efficiencies are assumed to be appropriate for the strains of dairy cattle in the trial. Furthermore, we had no true values of feed intake to compare our estimates, only feed offered and ME intake estimated from pre- and post-grazing masses plus supplements. It would have been useful to compare the estimates of intake derived using the equations to intakes derived using the alkane technique, however, these were only available for relatively short periods during the trial. Smit *et al.* (2005) compared intakes derived from alkanes, energy equations and pre- and post-grazing masses and concluded that alkanes were the most reliable way of estimating intake. However, their study used a relatively simple method of calculating intake using energy equations derived for housed cattle and required only fat and protein corrected milk and live weight in the calculation.

Based on target allowances, pasture utilisation was most efficient for lower amounts of feed offered. The NZ90s and NZ70s strains achieved estimated pasture utilisations of 95% and 91% respectively in 2003 at their respective lowest levels of feed offered. While high levels of feed utilisation are important for New Zealand dairy farms, it is only part of dairy farm profitability, Macdonald *et al.* (2001) demonstrated that for pasture utilisations ranging between 72% and 93%, maximum economic farm surplus (EFS) occurred at less than maximum feed utilisation. Results using data from this trial (Pryce *et al.,* 2005) support this finding.

The NZ70s strain responded from 4.5 to 5.5 tDM/cow by increases in feed intake per cow and milksolids per cow, but showed no further increases at 6 tDM/cow. Both the NZ90s and OS90s strains responded by increasing their intakes and yield of milk solids with higher levels of feeding up to 6.5 tDM/cow and 7 tDM/cow respectively. Penno *et al.* (2001) hypothesised that response to supplementary feeding was driven by the cow's relative 'energy deficit' defined as the difference between the cow's theoretical ME demand to achieve her target milk yield (genetic potential) and rate of live-weight gain, and her actual ME intake. Thus, genetic selection for higher production has resulted in cows that are capable of producing more milk solids per unit of maintenance costs, and achieving greater intake per kg of live weight. These changes lead to an increased proportion of energy partitioned to milk production (Equation 7) provided sufficient feed is available.

At similar levels of comparative stocking rate (defined as LWT/tDM), the NZ90s and OS90s strains at the highest allowance partition similar amounts of energy to milk production and can be considered to be similar in their energetic efficiencies. At the lower allowances (higher comparative stocking rate), the NZ90s appear to partition more energy to production. This is likely to be caused by higher maintenance and growth requirements of the OS90s strain at the lower levels of feeding and indicates that these cows are not suited to a grazing system with no supplements. This observation agrees with the data of Kolver *et al.* (2001). At restricted levels of feeding, the relative efficiencies of OS90s and NZ70s were very similar, yet the OS90s strain responds to extra feeding, while the NZ70s strain does not. Thus, the type of cow present in New Zealand in the 1970s could not respond to higher levels of feeding when compared to modern strains of cattle, yet the efficiency of conversion of feed to milk at similar moderate levels of feeding was comparable to modern strains of cattle.

The method for calculating proportion of energy partitioned to milk production (Equation 7) features estimated feed demand for milk production components in the calculation of both the numerator (energy requirements for milk production) and the denominator (total energy intake). In studies where pre- and post-grazing masses or alkanes are used to measure intake, the denominator (total energy intake) is independent of milk yield. The proportion of energy required for milk production was also calculated using ME intake estimated from pre- and post-grazing mass data plus actual supplements fed over the course of the trial as a denominator. The correlation of the proportion of energy partitioned to milk production calculated using the two measures of intake was 0.86, which provides some validation of the present data and conclusions.

Our results show that using energy prediction equations is a way in which feed intake estimates of lactating dairy cows can be estimated. ME intakes calculated in this way can then be used to elucidate differences in energy partitioning and other measures between strains/breeds of cows. The equations are especially valuable when individual ME intakes per cow are required and in circumstances where feed intakes are required over a long period of time. Furthermore, the measurements required to calculate ME intake are recorded on many dairy farms already, making it feasible to estimate feed intake indirectly using data from these herds.

ACKNOWLEDGEMENTS

This work was funded by Dairy InSight and Livestock Improvement Corporation. We thank farm and data recording staff for their efforts in caring for the animals and collecting and storing data.

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