

# Meta-analysis of the effect of forage type on the efficiency of utilization of energy for milk production in dairy cows\*

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## ABSTRACT

The study investigated the effect of forage type on maintenance energy ( $ME_m$ , MJ/kg BW<sup>0.75</sup> per day) requirement and the efficiency of utilization of metabolizable energy intake for milk production ( $k_l$ ). A database containing 652 observations was assembled from calorimetry studies. The data was subdivided into six sets. These were grass silage 1, maize silage 2, fresh grass 3, mixed silage 4, dried grass 5, and straw 6, based diets. Meta-analysis estimated the values of  $ME_m$  and  $k_l$  to be 0.54, 0.56, 0.56, 0.60, 0.72, 0.59, 0.54, 0.58, 0.55, 0.58 and 0.61, 0.60 for subsets 1-6, respectively. There was no significant difference in the estimate of fasting heat production (FHP) in all subsets except fresh grass. This resulted in a significant difference in  $ME_m$  when compared to cows fed other diets. Although differences in  $k_l$  were observed when data were fitted with fixed FHP, unconstrained fitting showed that  $k_l$  was about 59%.

KEY WORDS: energy metabolism, dairy cow, lactation

## INTRODUCTION

Metabolizable energy intake (MEI) at maintenance ( $ME_m$ ) and efficiency of utilization of MEI for milk production ( $k_l$ ) are key parameters in estimating energy requirements in dairy cows. There has been a wide range of reported values for  $ME_m$  and  $k_l$  in the literature and part of the reason could be differences in method of analysis

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and type of diet, particularly, the forage component offered. Yan et al. (1997a) reported that  $ME_m$  values significantly increased from 0.59 to 0.74 MJ/kg  $BW^{0.75}$  per day when forage proportion of silage in the diet increased from 50 to 100%. However, there is a lack of studies that investigate the effect of type of forage on  $ME_m$  and  $k_l$ . Accurate estimate of these values is important for feed evaluation purposes and recommendations for feeding lactating dairy cows. Recently, national recommendations for  $ME_m$  and  $k_l$  in the UK has been revised and new values of 0.65 MJ/kg  $BW^{0.75}$  and 0.60, respectively, were reported (Thomas, 2004). The objective of the study was to investigate the effect of forage type in dairy cow diets on  $ME_m$  and  $k_l$  using a large set of data and a novel technique developed by Kebreab et al. (2003a).

## MATERIAL AND METHODS

### *The database*

A database containing energy balance data for 652 dairy cow observations was assembled from calorimetry studies conducted in the UK. Details of diet composition of the trials used to construct the database and range of calorimetric data is summarized by Kebreab et al. (2003a). The database was divided into six datasets based on the main forage type in the diet offered. These were grass silage (n=338), maize silage (n=117), mixed forage (n=106), fresh grass (n=35), dried grass (n=26) and straw (n=31).

### *Mathematical and statistical considerations*

Kebreab et al. (2003a) developed a new method of analysing energy balance data from lactating dairy cows. They defined the efficiency of utilization of ME for milk energy ( $k_l$ ) as the derivative of milk energy derived from MEI divided by MEI directed towards maintenance and milk production. Instead of taking book values, the authors directly calculated the marginal efficiencies of utilization of MEI for growth (0.84) and body stores for milk production (0.66). These values were used to correct the raw data before MEI was regressed against milk energy. Although Kebreab et al. (2003a) found the linear and Mitscherlich functions to fit the data well, the linear equation only is used here as the parameter estimates from the Mitscherlich function were found not to be significant. The data was also fitted either unconstrained or fixing the intercept based on a reported fasting heat production (FHP) value of 0.326 MJ/kg of  $BW^{0.75}$  per day.

The analysis was conducted in PROC MIXED procedure in SAS (2000). Mixed model analysis was chosen because the data were gathered from various

studies and therefore it was necessary to consider analysing not only fixed effects of the dependent variable, but also random effects (because the studies represent a random sample of a larger population of studies).

## RESULTS

Parameter estimates obtained from unconstrained fit to data were all significant ( $P < 0.05$ ) and  $ME_m$  and  $k_l$  were calculated based on the parameter estimates. The calculated  $ME_m$  value shows that maintenance requirement in cows fed grass and mixed silage was among the lowest and those fed maize silage and dried grass had similar requirement (Table 1). However, cows fed fresh grass diets had significantly higher maintenance requirement. Cows fed straw also had higher  $ME_m$  values compared to those fed maize silage, dried and fresh grass. When the FHP value was fixed, the calculated  $ME_m$  value was similar among the forages offered except fresh grass which, on average, had 15% higher  $ME_m$  (Table 1).

Table 1. Parameter estimates and goodness of fit values when models were fitted (a) to the unconstrained and corrected data (b) by fixing the intercept to a measured fasting heat production value (0.32). Standard errors are given in brackets. Ranges of values given for metabolizable energy requirement for maintenance ( $ME_m$ ) and efficiency of utilization of ME for milk production ( $k_l$ ) are based on standard errors of the parameter estimates

| Item                        | Forage type     |                 |                |                 |                |              |
|-----------------------------|-----------------|-----------------|----------------|-----------------|----------------|--------------|
|                             | grass<br>silage | maize<br>silage | fresh<br>grass | mixed<br>silage | dried<br>grass | straw        |
| <i>a) Unconstrained fit</i> |                 |                 |                |                 |                |              |
| a                           | 0.30 (0.022)    | 0.33 (0.032)    | 0.43 (0.023)   | 0.32 (0.041)    | 0.32 (0.021)   | 0.37 (0.025) |
| b                           | 0.56 (0.023)    | 0.60 (0.018)    | 0.59 (0.071)   | 0.58 (0.018)    | 0.58 (0.013)   | 0.60 (0.014) |
| RSS <sup>1</sup>            | 0.0037          | 0.0037          | 0.0037         | 0.0037          | 0.0037         | 0.0037       |
| $r^2$                       | 0.80            | 0.81            | 0.62           | 0.93            | 0.83           | 0.98         |
| $ME_m$                      | 0.52 – 0.55     | 0.52 – 0.60     | 0.68 – 0.78    | 0.50 – 0.59     | 0.53 – 0.58    | 0.58 – 0.63  |
| $k_l$                       | 0.54 – 0.58     | 0.58 – 0.61     | 0.56 – 0.66    | 0.56 – 0.60     | 0.57 – 0.59    | 0.59 – 0.62  |
| <i>b) Fixed intercept</i>   |                 |                 |                |                 |                |              |
| b                           | 0.57 (0.015)    | 0.59 (0.027)    | 0.51 (0.039)   | 0.59 (0.016)    | 0.57 (0.032)   | 0.57 (0.014) |
| RSS <sup>1</sup>            | 0.0037          | 0.0037          | 0.0037         | 0.0037          | 0.0037         | 0.0037       |
| $r^2$                       | 0.78            | 0.81            | 0.51           | 0.93            | 0.81           | 0.98         |
| $ME_m$                      | 0.55 – 0.58     | 0.52 – 0.57     | 0.58 – 0.68    | 0.53 – 0.56     | 0.53 – 0.60    | 0.54 – 0.57  |
| $k_l$                       | 0.55 – 0.58     | 0.56 – 0.61     | 0.47 – 0.55    | 0.57 – 0.60     | 0.54 – 0.60    | 0.56 – 0.59  |

RSS<sup>1</sup> - residual sum of squares

$r^2$  - proportion of variation explained by the model

Comparison of  $k_f$  in cows fed various types of forages shows that the values were close to each other in unconstrained fitting except in grass silage fed animals which was found to be lower (Table 1). Some differences in  $k_f$  were observed when the data was fitted with a fixed FHP value. The estimate ranged from 0.47 in fresh grass based diet to 0.61 in maize silage based diet. In comparison with the other diets, the analysis showed a significant reduction of  $k_f$  in cows offered fresh grass.

## DISCUSSION

The effect of forage type on  $ME_m$  and  $k_f$  were investigated using a meta-analytical approach. The calculated FHP, based on the parameter estimates of the linear function, were not significantly different from that reported by Kebreab et al. (2003a) and NRC (2001), which is 0.335 MJ/kg  $BW^{0.75}$  per day for all forage types except fresh grass. The higher maintenance requirement in cows fed fresh grass and straw based diets could be associated with higher energy cost of digestion due to fibrous nature of grass and straw. Similar values of  $ME_m$  were reported by Yan et al. (1997a) in cows offered diets in which the forage proportion of diet was high. There is also a confounding effect of forage:concentrate (F:C) ratio. The cows offered fresh grass had an F:C ratio of 0.62 to 1.0. Kebreab et al. (2003b) reported that cows fed high forage diets had also significantly higher maintenance requirement.

Grass silage fed cows showed lower  $k_f$  compared to cows fed the other diets partly because of confounding with level of concentrate offered. About 25% of the cows offered grass silage based diets had less than 20% concentrate in their diet, thus reducing the efficiency of energy utilization for milk. Yan et al. (1997a) also found a decrease in efficiency in cows with higher proportion of forage in their diet. Similarly, there was a lower  $k_f$  value when data was fitted with fixed FHP value, partly because the linear model predicted a higher intercept so the slope ( $k_f$ ) was lower. Yan et al. (1997b) reported an FHP value similar to the one found here in grass silage based diet, therefore, it is likely that fresh grass fed cows had a higher FHP requirement and higher  $ME_m$  rather than significantly lower  $k_f$ .

## CONCLUSIONS

Analysis of energy balance data using 652 dairy cow observations showed that the linear model used produced statistically significant parameter estimates which were used to calculate  $ME_m$  and  $k_f$  values for different types of diets investigated. Cows fed fresh grass and straw had a higher maintenance requirement probably due to higher energy requirement for digestion of fibrous material. Similarly, fresh grass fed cows showed less efficiency in converting feed to milk.

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