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## BRIEF COMMUNICATION: Estimation of protein utilization efficiency and metabolisable protein efficiency in lactating cows grouped by breeding worth

NW Wheaton<sup>ab</sup>, L Cheng<sup>a\*</sup>, RJ Dewhurst<sup>b</sup> and GR Edwards<sup>a</sup>

<sup>a</sup>Faculty of Agriculture and Life Sciences, PO Box 85084, Lincoln University, Lincoln 7647, New Zealand; <sup>b</sup>Animal Bioscience Centre, Teagasc, Dunsany, County Meath, Ireland

\*Corresponding author. Email: long.cheng@lincolnuni.ac.nz

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### Introduction

The efficiency of conversion of feed protein to milk protein (protein use efficiency (PUE)) is important in ruminants as protein is the most valuable component of milk (Ryan et al. 2011). It is also essential to reduce nutrient and resource costs when the efficiency of nutrient use is low (Roberts, 2008). In ruminants, dietary protein has three main routes of metabolism, namely microbial fermentation in the rumen, absorption in the small intestine, and catabolism and excretion of excess digestible protein into faeces and urine nitrogen (Agricultural Research Council 1980). This makes PUE difficult to explain and predict because of the interaction of these pathways. Rumen degradable protein (RDP) and metabolisable protein (MP) are the two main protein pools for milk protein production. Inefficient use of either would result in increased urine nitrogen excretion (Lapierre et al. 2005).

Breeding worth (BW) is used to rank animals that are most efficient at creating profit and as such are high value replacements. It has been previously reported that there are genetic differences between animals in respect of energy metabolism and production (Woodward et al. 2011). As a consequence we would predict differences in protein partitioning based on previous findings by Wheaton et al. (2012), who noted differences in nitrogen use efficiency between high and low BW cows.

The aim of this study was to estimate and compare total dietary protein efficiency (PUE) and metabolisable protein efficiency (MPE) (g milk protein/g MP), and their relationship with breeding worth (BW).

### Materials and methods

Milk samples from 200 lactating cows on the Lincoln University Dairy Farm (New Zealand) were collected in February 2012 (late lactation) and sent for analysis of their milk protein, fat and lactose content (LIC, Hornby, New Zealand). Animals were grouped into either a high BW group (n=100) consisting of cows with a BW higher than 140, or a low BW group (n=100) consisting of cows with a BW lower than 75. Animals were rotationally grazed on perennial ryegrass and clover paddocks. Herbage samples were taken the day before milk sampling for analysis of nitrogen content (%) and metabolisable energy (ME)

(MJ/kg/dry matter (DM)) (Analytical Research Laboratories Ltd., Napier, New Zealand). Animal live weight (LW) and daily milk yield were recorded at the milking shed, and BW values were obtained from the current farm database.

### Prediction calculations

Dry matter intake (DMI) (kg/day) was estimated by back-calculations using equations from Nicol & Brookes (2007). Predictions were made by calculating total ME requirements as the sum of ME for maintenance (ME<sub>Maintenance</sub>), lactation (ME<sub>Lactation</sub>) and activity (ME<sub>Activity</sub>) where:

$$ME_{\text{Maintenance}} \text{ (MJ/day)} = (0.56 \text{ MJ ME/kg LW}^{0.75},$$

$$ME_{\text{Lactation}} \text{ (MJ/day)} = (1.1 \times \text{Milk yield (kg/day)} \times \text{Net energy (NE)/k (Efficiency with which ME is utilized)}) \text{ where NE} = (0.376 \times \text{Fat \%}) + (0.209 \times \text{Protein \%}) + 0.976 \text{ MJ NE/litre, and k} = (\text{Feed ME MJ/kg DM} \times 0.02) + 0.4 \text{ and}$$

$$ME_{\text{Activity}} = (0.0037 \text{ MJ ME/kg LW per horizontal km walked}).$$

Dry matter intake (kg/day) was then estimated as total ME requirement (MJ/day) divided by feed ME (MJ/kg DM). Predictions of PUE (g/g) were made by dividing feed protein (g/day/cow) by milk protein (g/day/cow).

Metabolisable protein supply (MP) (g/day) was estimated by  $(0.64 \times \text{Microbial protein}) + (0.9 \times (\text{Undegradable dietary protein (UDP)} - (\text{Acid detergent insoluble nitrogen fraction (ADIN)} (\text{g/kg DM}) \times 6.25))) \times \text{DMI (kg/day)}$ , where  $\text{UDP} = \text{Crude protein \%} \times (1 - \text{Quickly degraded protein (QDP)} + \text{Slowly degraded protein (SDP)}) \times 10$ . For additional calculation details refer to Brookes & Nicol (2007). Assumed protein degradation values for pasture were used for QDP and SDP as these were not included in the chemical analyses that were undertaken in this study: Soluble protein fraction = 0.53 g/g crude protein, insoluble degradable fraction = 0.42 g/g crude protein, fractional protein disappearance rate = 0.14%/hour, ADIN = 0.30 g/kg DM. Metabolisable efficiency (g/g) was estimated as milk protein (g/d) divided by MP supply (g/d). Linear regression and analyses of variance were conducted in GenStat (Payne et al. 2009) between MPE and PUE and effect of BW as a treatment group.

**Table 1** Mean values for the measured production and calculated efficiency variables in 100 cows with a Low breeding worth and 100 cows with a High breeding worth, the standard error of the difference and the associated P value. Bold text indicates significance at  $P < 0.05$ .

Variable	Breeding worth group		Standard error of difference	P value
	Low	High		
Breeding worth	54	159	2	<b>&lt;0.001</b>
Live weight (kg)	502	475	7	<b>&lt;0.001</b>
Dry matter intake (kg/day)	15.7	14.9	0.4	<b>0.04</b>
Nitrogen intake (g/day)	750	710	19	<b>0.04</b>
Milk yield (kg/day)	16.6	16.0	0.6	0.23
Milk nitrogen (g/L)	6.71	7.05	0.08	<b>&lt;0.001</b>
Milk protein (g/L)	42.8	45.0	0.5	<b>&lt;0.001</b>
Protein use efficiency (g/g)	0.147	0.157	0.002	<b>&lt;0.001</b>
Metabolisable protein efficiency (g milk protein/g metabolisable protein)	0.283	0.302	0.004	<b>&lt;0.001</b>
Feed conversion efficiency (g/g)	0.115	0.115	0.001	0.78

## Results

Pasture crude protein concentration was 29.8% and metabolisable energy was 12.1 (ME MJ/kg DM). Live weight, intake, milk composition and efficiency estimates were significantly different between the Low and High BW groups (Table 1).

There was a significant positive correlation between estimated PUE and MPE ( $r^2 = 0.93$ ;  $P < 0.001$ ), which was similar among the Low and high BW groups ( $r^2 = 0.92$ ;  $P < 0.001$ ) and ( $r^2 = 0.93$ ;  $P < 0.001$ ) respectively. The relationship between BW and predicted MPE and PUE was significant, but a weak predictor of both PUE ( $r^2 = 0.10$ ) and MPE ( $r^2 = 0.12$ ).

## Discussion

Based on the assumption that animals in the experiment were in zero energy balance, high BW animals had a lower estimated DMI and a lower nitrogen intake. This is in contrast to previous findings by Woodward et al. (2011) who noted high BW animals had a higher DMI and a higher nitrogen intake. In addition, our results showed high BW cows had a lower live weight and a higher milk protein and milk nitrogen output. Both High and Low BW groups maintained a similar milk yield, which suggested that the High BW cows had a higher genetic potential for increased feed utilisation for the production of milk protein than the Low BW cows (Dewhurst et al. 2002). This means feed requirements of High BW animals would be lower due to their lower maintenance requirements (lower metabolic body weight) and also have higher gram per gram conversion of feed to milk protein than Low BW cows. There was no difference in milk yield for High BW cows compared to Low BW cows which is likely due to past feeding regimes whereby cows were unable to reach their maximum

intake (Allen 2000), and therefore unable to consume sufficient energy. There was no difference in feed conversion efficiency (FCE; milk solids kg/DMI kg) between High and Low BW groups (Table 1), suggesting that specific nitrogen partitioning differences, such as PUE, may occur between animals of differing genetic merit.

### Genetic basis of efficiency pathways

The higher estimated efficiency of High BW cows than Low BW cows is in agreement with findings from Woodward et al. (2011) who used N balance techniques for recording DMI. The difference between the High and Low BW groups for PUE and MPE was small (1–2%) therefore there is difficulty in assessing the difference in metabolic efficiency between groups when crude protein levels were high (29%). Cows eating crude protein closer to their requirements of 16% have showed a 4% difference in nitrogen efficiency between High and Low BW groups (Woodward et al. 2011). The relationship between BW with PUE and MPE was weak within High and Low groups in this study. This is in contrast to findings from Wheadon et al. (2012) who found a significant positive relationship between BW and nitrogen use efficiency of  $r^2 = 0.60$  using recorded intakes. This inconsistency indicates that using BW as a predictor of protein efficiency may not be suitable when used alone.

The weak relationship between BW and protein efficiency observed in this study may result from the weightings of other traits in the BW index, some of which, such as longevity and fertility, do not relate to components of efficiency. However, the results do show that animals with a higher BW have higher MPE and PUE, and partition more nutrients to milk, as reported by Davey et al. (1983). This variation in performance is due to genetic differences between high and low BW animals in both nutrient partitioning and

regulation of protein metabolism pathways (McPherron and Lee, 1997), contrary to older research by Trigg & Parr (1981) who suggested there was no relationship between genetic merit and ME efficiency. During lactation, higher BW cows may have increased their ability to partition nutrients to the mammary gland to increase lipogenesis (Bauman & Currie 1980).

The results in this study include estimations of intake and efficiency, and assumptions of ME requirements. This makes it difficult to reach conclusions. Previous correlations between estimates of DMI and PUE, with measured DMI ( $r = 0.71$ ) and PUE ( $r = 0.86$ ) reported by Wheadon et al. (2012) have provided some confidence to the results in this study. There are several systems to estimate DMI which are based on many different physiological factors and measurements (National Research Council, 1985). The estimates used in this study need further investigation before drawing conclusions based on one example system. In addition, degradability of crude protein in the rumen can vary and information is limited. Chaves et al. (2006) found that the soluble crude protein fraction of perennial ryegrass mature leaves ranged from 35% to 61% of the crude protein fraction, and effective rumen degradable protein ranged from 49 (g/kg DM) for stem to 124 (g/kg DM) for leaf. Hence, MPE calculations using assumed protein degradation values as used here are likely to be a source of variation affecting assumptions of metabolisable protein supply.

In this study, MPE was relatively high compared to PUE. The lower PUE may have been because of the high nitrogen intake and because cows appeared more efficient in pathways involving the metabolism of metabolisable protein. Breeding worth may be useful to identify animals which have higher MPE and PUE but may not be a suitable predictor of protein efficiency alone.

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