
VOLUME 62 2002

Feeding behaviour differs between dairy calves selected for divergent feed conversion efficiency

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ABSTRACT

Feeding behaviour and efficiency of feed utilisation, measured as residual feed intake (RFI; defined as actual feed intake minus predicted feed required), were measured in dairy calves aged six to seven months-old, and associations between the two variables were determined. The intake, feeding behaviour, and live weight of 219 female Holstein-Friesian calves were recorded for 46 days. Animals were housed in an outdoor facility comprising 28 pens, each with a single-access feeder containing dried, cubed lucerne. Efficient animals were associated with lower intakes (r^2 = 0.29), fewer meals/day (r^2 = 0.05), less time spent eating/day (r^2 = 0.03), and slower eating rates (r^2 = 0.03). The 30 most efficient animals consumed less (mean ± standard error of difference; 6.15 vs 7.46 ± 0.20 kg cubes/day), had fewer meals (4.03 vs 4.85 ± 0.29 meals/day), and spent less time feeding (2.68 vs 2.93 ± 0.11 hours/day) compared to the 30 least efficient animals (all $P < 0.05$). Rate of liveweight gain, eating rate, amount eaten per meal, and meal duration did not differ between the 30 most efficient and 30 least efficient animals ($P > 0.05$). In conclusion, differences in feeding behaviour were found between dairy calves selected for divergence in efficiency which may have implications for their management.

Keywords: feed conversion efficiency; residual feed intake; feeding behaviour; dairy cattle.

INTRODUCTION

Cattle differ in the efficiency with which they use feed for liveweight gain. This is sometimes referred to as residual feed intake (RFI) or net feed intake, defined here as the actual intake minus the predicted feed requirement of an animal (Herd & Arthur, 2009). Predicted feed requirements are calculated based on animal live weight and level of performance. Individual measurement of feed intake in conjunction with liveweight gain, usually over a period of several weeks, enables animals that use their feed efficiently or inefficiently to be identified.

The biological mechanisms controlling RFI are not fully understood, but include digestion, physiological demands for nutrients and biochemical efficiencies of feed utilisation (Herd & Arthur, 2009). Feeding behaviour may contribute to variation in efficiency through the energetic costs associated with feeding activity, such as time spent feeding, rate of eating, and nutrient supply (Richardson & Herd, 2004; Lancaster *et al.*, 2009; Kelly *et al.*, 2010). Feeding behaviour also affects intake, which will influence both production and RFI.

Published studies with beef cattle showed that animals of divergent RFI differed significantly in their feeding behaviour (Nkrumah *et al.*, 2007; Lancaster *et al.*, 2009). The measured behaviours included feeding frequency, daily feeding duration, eating rate, meal amount, and meal duration. However, these studies have given highly variable results, with each feeding characteristic explaining between 2% and 24% of the variation in RFI (Robinson & Oddy, 2004; Nkrumah *et al.*, 2007; Lancaster *et al.*, 2009; Kelly *et al.*, 2010; Montanholi *et al.*, 2010). No studies have been undertaken with dairy cattle fed forage diets.

An understanding of factors associated with RFI, such as feeding behaviour, will provide a better understanding of the mechanisms regulating efficiency and could help predict RFI if relationships are sufficiently high (Nkrumah *et al.*, 2007; Montanholi *et al.*, 2010). An improved understanding of feeding behaviour could improve animal management, lessen stress and improve production.

This study was undertaken to measure differences in feeding behaviour of six to seven month-old dairy heifers during a screening procedure to identify individuals with negative RFI (efficient) and positive RFI (inefficient). We hypothesised that there would be differences in behavioural characteristics of efficient and inefficient individuals and that these characteristics would be associated with RFI.

MATERIALS AND METHODS

Animals and facility

This study used data collected from 219 female Holstein-Friesian calves of approximately six to seven months of age (167 ± 16.5 kg live weight) in 2009. The animals were kept in an outdoor feeding facility at the Westpac Taranaki Agricultural Research Station, Hawera. Calves were randomly allocated to 28 pens with eight animals in most pens at the commencement of the trial; they were held in these pens for an 11-day adaptation period followed by a 46-day trial period. Each pen was 42 m^2 (6 m x 7 m), had bedding of post peelings and a single feeding station, enabling only one animal to have access to the feed at a time. Calves were fed dried lucerne cubes (Kapt-al, Vancouver, Canada), and both water and salt blocks were freely available. The cubes averaged 84.5% dry matter (DM) and contained 18.7% crude protein and 45.8% neutral detergent fibre in the DM with a predicted organic matter digestibility of 65.0% (FeedTECH, AgResearch, Palmerston North). Allocation of eight animals per pen was based on preliminary evaluations that showed that sufficient time was available for eight animals to eat *ad libitum* from a single feeding station. This trial was one group of a larger evaluation using 1,050 dairy calves to identify those with divergent efficiencies of feed utilisation (Carnie *et al.*, 2010).

Data recording and analyses

Data used for this analysis comprised feed intakes, animal electronic identification (EID: SmartReader R600 panel reader, Gallagher Ltd., Hamilton), the time that individuals ate from the feed bin, and individual live weight measured three times per week. Intake, calculated from changes in feed bin weight at each individual feeding event by each individual calf, and feeding behaviour were recorded each second for the duration of the trial by an automatic recording system developed by Gallagher Ltd., Hamilton. Feed bin weight was measured by two load bars (SmartScale 300 weigh scale, Gallagher Ltd., Hamilton) located beneath each bin. Animals were identified upon entry to the bin by an EID reader positioned over the feed bin. Data were processed so that information from all 28 feed bins was received and logged onto two computers at one-second intervals. These data were formatted and checked for accuracy prior to analysis.

The data used for analysis of feeding behaviour included average daily intake, number of meals per day, time spent feeding per day (hours/day), daily eating rate (g/minute), meal amount (kg cubes/meal), and meal duration (minutes/meal). A "meal" was defined as being a feeding event in which ≥0.01 kg was consumed. The meal began when the animal put its head into the feed bin and ended when the animal left the feed bin for more than 15 minutes, or when another animal entered the feed bin.

Residual feed intake

Determination of RFI in this study was calculated as the difference between actual intake and the predicted feed requirements of individual animals. Predicted feed requirements were calculated for the 219 animals by regressing actual daily feed intake (kg cubes/day) against liveweight gain (kg/day) and mean metabolic live weight ($kg^{0.75}$). Average liveweight gain was calculated by regression analysis of live weight versus time, over the 46-day measurement period. The resulting equation was:

Predicted feed requirements (kg cubes/day)
= 1.44 kg/day liveweight gain +
0.19 kg $\text{liveweight}^{0.75}$ – 3.4 (r^2 = 0.61).

Hence, residual feed intake (RFI), the measure of efficiency used in this paper, is determined as the amount actually consumed by a calf (kg cubes/day) minus the predicted feed requirement calculated for that calf from the above equation. More efficient animals have negative values for RFI, as the amount that they actually eat is less than their predicted feed requirements; whereas less efficient animals have positive values for RFI.

Statistics

Associations between RFI and each feeding behaviour characteristic of all 219 animals were calculated by regression using GenStat (Payne *et al.*, 2009). Comparisons of each feeding behaviour characteristic between the 30 most and 30 least efficient animals (divergent RFI) used ANOVA.

RESULTS

Results from all the animals

The animals accepted the cube diet and appeared to adapt to the feeding facility with ease during the adaptation period. Mean intakes ± standard error of the mean were 6.86 ± 0.78 kg cubes/day (5.82 ± 0.66 kg DM/day) for all 219 animals over the 46-day measurement period. The average daily liveweight gain was 0.80 ± 0.12 kg/day over the 46-day measurement period, with lowest and highest values of 0.47 and 1.09 kg/day, respectively. Average daily intakes increased from 5.80 to 7.57 kg cubes/day (standard error of difference (SED) = 0.07) from the commencement to the end of the experimental period. The time spent eating within a 24 hour period averaged 2.90 ± 0.43 hour, with 4.7 ± 1.3 meals and an average eating rate of 40.8 ± 7.9 g cubes/minute, increasing from 34.9 to 45.4 g/minute (SED = 0.48) from the commencement (Days 1-5) to the conclusion (Days 41-46) of the trial.

All the feeding behaviour characteristics measured had statistically significant associations with RFI (Table 1; $P<0.05$), with the exception of meal amount. Efficient animals had lower daily feed intakes, spent less time feeding per day, ate more slowly and had fewer meals of longer duration than inefficient animals (Table 1). An example of the distribution of data is given in Figure 1 where the average number of meals per day over the duration of the trial is plotted against RFI. Although the relationship was highly significant ($P < 0.001$), this variable accounted for only 5% of the variation in RFI.

Comparison of 30 most and 30 least efficient animals

The 30 most and 30 least efficient animals had a similar average live weight and daily liveweight gain (Table 2). The most efficient animals (negative RFI) consumed less feed, had fewer meals, and spent less time eating than did the least efficient animals (positive RFI) (Table 2; $P < 0.05$). There were no differences in eating rate, meal duration, or meal amount between efficient and inefficient animals (Table 2).

DISCUSSION

The feeding facility and diet enabled good rates of gain, similar to about 0.77 kg/day reported for Holstein-Friesian animals of a similar age fed *ad libitum* on high quality pasture and silage (Macdonald *et al.*, 2005). Analysis of feeding behaviour identified significant differences between efficient and inefficient calves. In addition to differences in feed intake, which is a component of RFI, analyses involving all 219 animals, and the comparison between the 30 most efficient animals and the 30 least efficient animals, showed that efficient animals ate fewer meals and spent less time feeding per day. Meal amount was not different between efficient and inefficient animals in either analysis. The slower eating rate and longer meal durations associated with efficiency in all the 219 calves were not evident in the comparison of the 30 most and 30 least efficient calves. Daily feed intake was moderately associated with RFI. This has also been found in studies on beef cattle (Robinson & Oddy, 2004; Lancaster *et al.*, 2009). The r^2 values for the associations between RFI and each of the other feeding behaviour characteristics (Table 1) were low, suggesting their contributions to RFI were small, despite being

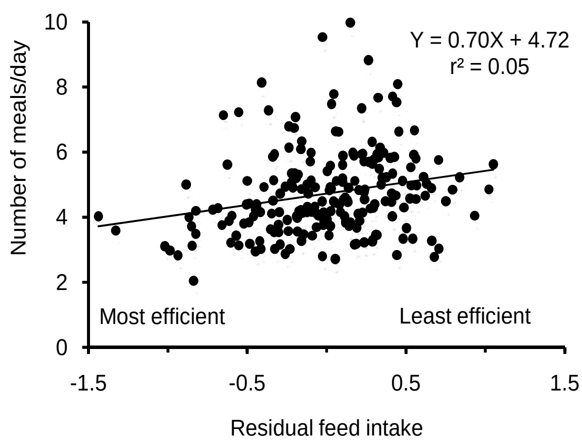
TABLE 1: Relationships between residual feed intake (kg cubes/day) and feeding behaviour characteristics averaged from all the 219 experimental calves fed lucerne cubes for 46 days. Bolding of P values indicates significance ($P < 0.05$).

Measurement	Slope	Standard error of slope	P value	r^2
Daily feed intake (kg cubes/day)	0.97	0.10	**<0.001**	0.29
Number of meals per day	0.70	0.20	**0.001**	0.05
Time spent feeding per day (hours/day)	0.17	0.07	**0.010**	0.03
Daily eating rate (g/minute)	3.24	1.22	**0.008**	0.03
Meal duration (minutes/meal)	-4.18	1.75	**0.02**	0.03
Meal amount (kg cubes/meal)	-0.02	0.06	0.74	0.00

TABLE 2: Mean values for live weight as the midpoint of the regression over the 46-day trial, daily liveweight gain and feeding behaviour characteristics of the 30 most efficient and 30 least efficient calves fed lucerne cubes for 46 days. Bolding of P values indicates significance ($P < 0.05$).

Measurement	Feed utilization		Standard error of difference	P value
	Efficient	Inefficient		
Live weight (kg)	172.9	173.1	4.95	0.96
Daily liveweight gain (kg/day)	0.78	0.76	0.04	0.67
Daily feed intake (kg cubes/day)	6.15	7.46	0.20	**<0.001**
Number of meals per day	4.0	4.9	0.29	**0.007**
Time spent feeding per day (hours/day)	2.68	2.93	0.11	**0.02**
Daily eating rate (g/minute)	40.1	43.7	2.51	0.16
Meal duration (minutes/meal)	46.0	41.7	3.46	0.21
Meal amount (kg cubes/meal)	1.73	1.71	0.09	0.87

FIGURE 1: The relationship between number of meals per day and residual feed intake of 219 calves fed lucerne cubes for 46 days.



statistically significant. Significance was due in part to the large number of animals used, but the associations with feeding characteristics were too small to be used as predictors of RFI in these animals.

The associations reported in the present paper between each of five feeding behaviour traits and RFI were at the lower end of the range of those obtained in beef studies. For example, number of meals per 24 hours explained 0.05 of the variance in RFI in the present study, while values for beef cattle explained 0.03 to 0.20 of the variance (Robinson & Oddy, 2004; Nkrumah *et al.*, 2007; Lancaster *et al.*, 2009; Kelly *et al.*, 2010). There were also large ranges in the amount of variance in RFI accounted for by other traits in beef cattle, such as time spent eating/day, 0.03 to 0.24; and eating rate, 0.02 to 0.19 (Robinson & Oddy, 2004; Nkrumah *et al.*, 2007; Lancaster *et al.*, 2009; Kelly *et al.*, 2010; Montanholi *et al.*, 2010). Meal duration was negatively associated with RFI in this study (r^2 = 0.03), and in one beef study (Montanholi *et al.*, 2010), but Lancaster *et al.* (2009) reported a positive association with RFI (r^2 = 0.17). The association between meal amount and RFI was not statistically significant in the present study, but Montanholi *et al.* (2010) reported a significant association with RFI (r^2 = 0.17). The varying associations between studies suggest other factors are having a large effect on behaviour, and perhaps RFI. For example animal age, breed, diet, feeding facilities and analytical interpretation may all be having an effect. Nevertheless, the weak associations reported in the present paper between feeding behaviour characteristics and RFI suggest that feeding behaviour accounts for a small portion of the difference between animals, with digestion and metabolic factors such as protein synthesis and cellular ion fluxes probably explaining a larger portion of differences in efficiency (Herd & Arthur, 2009).

When the extremes in RFI were compared in this study, efficient animals had lower daily consumption, spent less time eating/day, and had fewer meals/day than inefficient animals. Meal amount, meal duration, and eating rate did not differ, suggesting these traits were less important. These findings correspond with measurements from beef animals, where most studies showed efficient animals had fewer meals (Nkrumah *et al.*, 2006; Bingham *et al.*, 2009; Kelly *et al.*, 2010), although Dobos and Herd (2008) reported no differences. Most studies reported no difference between efficient and inefficient animals in time spent eating (Dobos & Herd, 2008; Bingham *et al.*, 2009; Kelly *et al.*, 2010; Montanholi *et al.*, 2010) in contrast to findings reported here and those of Nkrumah *et al.* (2006) where efficient animals ate for less time per day. There is a lack of consensus in the literature relating RFI and eating rate. No differences were found here or by Dobos and Herd (2008) or Golden *et al.* (2008), whereas Bingham *et al.* (2009), Kelly *et al.* (2010) and Montanholi *et al.* (2010) found efficient beef cattle ate faster than inefficient animals.

In summary, there are large differences between the published results of studies investigating associations between feeding behaviour and RFI. This is likely to be due to differences in the experimental designs of these studies, suggesting that behaviour is sensitive to circumstances. In particular, differences in the numbers of animals used, the facility or housing set-up, the group size and density of the animals, and the diet fed have a large impact on feeding behaviour (Grant & Albright, 2001; Phillips, 2004; Huzzey *et al.*, 2006; DeVries & von Keyserlingk, 2009). In the work presented here, feeding behaviour explained a small proportion of the differences in RFI between animals, although it was not clear whether differences in feeding behaviour contributed to differences in efficiency or whether efficiency was driving feeding behaviour. However, differences in feeding behaviour may have implications for management of efficient animals. The results obtained here need further evaluation when the divergent groups are grazing pasture.

ACKNOWLEDGEMENTS

The authors would like to thank Barbara Dow for her statistical expertise and the Westpac Taranaki Agricultural Research Station technical team for daily management of the calves. This project was funded by DairyNZ Inc., Livestock Improvement Corporation, Trade and Enterprise, and the Foundation for Research, Science and Technology.

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