New Zealand Society of Animal Production online archive

Effect of genetic merit on the estimated partitioning of energy towards milk production or liveweight gain by Jersey cows grazing on pasture

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ABSTRACT

Data from the 1999/2000 season of the Stratford demonstration farm stocking rate trial was used to estimate metabolisable energy intakes (MEI) and the amount of metabolisable energy (ME) partitioned into milk, maintenance and liveweight (Lwt) changes of Jersey cows of either high genetic merit (HGM) (average milksolids breeding value of 28 kg) or low genetic merit (LGM) (average milksolids breeding value of 11kg). Least-square mean yields for HGM and LGM cows were 327 and 289 kg of milksolids per cow respectively. HGM cows partitioned a significantly higher proportion of MEI into milk than LGM cows in early (0.67 vs 0.63; $P<0.01$), peak (0.59 vs 0.57; $P<0.05$), mid (0.58 vs 0.56; $P<0.01$) and late lactation (0.54 vs 0.51; $P<0.01$) (HGM vs LGM respectively). In early lactation, HGM cows utilised more body reserves for milk production (-0.05 vs –0.01, for HGM and LGM respectively). These results confirm that HGM cows partition more ME to milk throughout lactation than LGM animals for a range of feeding levels on grazed pasture. The greatest difference occurred in early lactation, resulting in increased body tissue loss and a greater negative energy balance in HGM cows.

Keywords: partitioning; genetic merit; energy; pasture-based; energy balance; dairy cows.

INTRODUCTION

High genetic merit (HGM) dairy cows achieve higher values for gross efficiency than low genetic merit (LGM) dairy cows, mainly because they achieve higher milk yields, have slightly higher feed intakes and mobilise more body reserves (Fulkerson *et al.*, 2000; Buckley *et al.*, 2000; Ferris *et al.*, 1998a). The higher gross efficiency occurs despite the apparent absence of any difference in partial efficiency of ME use for lactation (Ferris *et al.*, 1998b). Consequently, the higher milk yields of HGM cows are largely attributable to greater partitioning of nutrients into milk, rather than compensatory increases in food intake or metabolic efficiency (Mayne & Gordon, 1995).

Considerable effort has been directed towards modelling the complex biochemical pathways that comprise metabolism at the tissue level. This has improved understanding of the factors that influence milk and tissue responses to changes in energy intake (Kirkland & Gordon, 2001). However, there is a lack of research at the whole animal level on energy partitioning by cows of different genetic merits when grazing on pasture (Saama & Mao, 1993). The aim of the present research is to quantify differences in energy partitioned to milk production and liveweight (Lwt) change at each stage of lactation by HGM and LGM dairy cows grazing at different feed levels achieved by different stocking rates.

MATERIALS AND METHODS

The data were derived from a trial using Jersey cows carried out at the Stratford Demonstration farm from July 1998 to May 2001. In this study, only data for the 1999/2000 season was used, because the data sets for the other two years were incomplete. Cows were allocated to one of four feeding levels (achieved by the use of four stocking rates); high (2.5 cows/ha), medium (3.2 cows/ha), low (3.7 cows/ha) or very low (4.2 cows/ha). Little supplement was fed, and was generally high-quality pasture silage conserved on the farmlets. Approximately 40 animals were allocated to each feeding level treatment. Data for the milk yields, and milk fat and protein concentrations were obtained at two-weekly intervals for each cow during the 1999/2000 season. Individual cow Lwts were measured on seven occasions starting on the 4th of September 1999 and finishing on the 3rd of April 2000. Pasture samples were collected from paddocks grazed by each treatment group at the time of the two-weekly herd tests, and the concentration of metabolisable energy of the consumed pasture was estimated by NIRS analysis (Corson *et al.*, 1999).

Calculation of estimated individual energy intakes

Energy intakes for each cow in the trial were calculated at intervals of two weeks to coincide with each herd test, using data for Lwt and change in Lwt, milk yield and composition, and energy concentrations of pasture. Individual cow Lwt changes were estimated from the difference in Lwt between consecutive Lwt measurements around the date of the herd test.

The ME requirements for lactation (M_l), maintenance (M_m), Lwt change (M_g) and MEI were calculated as proposed by AFRC (1993) with the following amendments:

Agnew & Yan (2000), in reviewing 42 recent studies, found the equations of the Agricultural and Food Research Council (1993) underestimated the fasting metabolism (F_m) of HGM cows by 20-30%. From the summary of these studies, a value for F_m requirements of 0.40 $Lwt^{0.75}$ has been adopted, which is 25% higher than the value proposed by AFRC (1993). In addition, an activity allowance (A_c) of 0.016 Lwt has been used, assuming a cow walking 3km daily and grazing pasture (Lopez-Villalobos, 1998) .

Partitioning of metabolisable energy

The amounts of energy partitioned to lactation (EP_l),

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maintenance (EP_m), Lwt change (EP_g) were calculated using:

$EP_l = M_l / MEI$

$EP_m = M_m / MEI$

$EP_g = M_g / MEI$

Statistical analysis

Animals were divided into two groups; LGM with a milksolids estimated breeding value (EBV) of <20 kg, and HGM with a milksolids EBV of >20 kg. Four lactation stages were defined; early (<60 days in milk), peak (60 to 120 days in milk), mid (120 to 180 days in milk), and late (180 to 240 days in milk). The cows were grazed at four levels of feeding; high, medium, low and very low. Energy partitioned to lactation, maintenance and Lwt change by individual cows in each lactation stage was analysed using the PROC MIXED procedure of SAS (2001). The model included the fixed effects of feeding level, lactation stage, genetic merit, age, and the interactions between genetic merit, lactation stage and feeding level. Repeated measures for each cow within each feeding level were considered. Using Akaike's information criterion, a compound symmetric structure of the residuals provided the best fit for the data.

RESULTS AND DISCUSSION

Least-square means and standard errors of EBVs, production and Lwt data of the two genetic groups, are shown in Table 1. The difference in estimated breeding value for milksolids between the groups was 17.6 kg. This difference is small compared to differences found within and between commercial herds (Livestock Improvement, 2001). HGM animals had significantly (P<0.001) higher daily milksolids (MS) yields than LGM animals throughout lactation, and significantly (P<0.05) higher total MS yields (327 vs 289 kg MS/cow, for HGM and LGM, respectively). However, the actual difference in MS yield (38 kg) was greater than the difference predicted by the estimated breeding values for MS (18 kg). For further discussion see Bryant *et al.*, (2003). The differences in Lwt between the two genetic groups were significant in early, mid and late lactation, but not in peak lactation, and the actual differences in Lwt were slightly greater than the difference in estimated breeding values for Lwt between each genetic group.

Estimated MEI and the proportions of energy partitioned to maintenance, lactation and Lwt change in HGM and LGM cows are presented in Table 2. HGM cows partitioned a significantly higher proportion of MEI to milk than the LGM cows in early (0.67 vs 0.63), peak (0.59 vs 0.57), mid (0.58 vs 0.56) and late lactation (0.54 vs 0.51) (HGM vs LGM respectively). The proportions of energy partitioned to milk were similar to those reported by Grainger *et al.* (1985), Oldenbroek (1986) and Yan *et al*. (2002). Jersey heifers fed a high-roughage diet partitioned 81, 62 and 54% of MEI to milk for 0-91, 92-182 and 183-273 days of lactation respectively, while the combined Holstein-Friesian and Dutch Red and White heifer groups partitioned 67, 53, and 49% of MEI to milk at the same respective stages of lactation (Oldenbroek, 1986). Grainger *et al.* (1985) reported the difference in the proportion of energy partitioned to milk between two genetic groups of cows was maintained throughout the lactation, whereas in this study, a slight reduction in the differences between the genetic groups was observed as the lactation proceeded (Table 2).

There was a significant (P<0.001) reduction in the proportion of MEI partitioned into milk as the lactation proceeded in both LGM and HGM animals (Table 2). This was similar to results of calorimetric studies with cows fed diets consisting of straw, concentrates and lucerne (Kirkland & Gordon, 2000) or cut pasture (Grainger *et al.*, 1985).

The largest significant difference (P<0.001) in EP_l between the genetic merit groups was measured in early lactation (0.67 and 0.63 for HGM and LGM animals, respectively; Table 2). The higher proportion of MEI partitioned to milk at this time was due to greater mobilisation of body tissue (EP_g) in HGM (-0.05) compared to LGM (-0.01) cows. Yan *et al.* (2002) and Snijders *et al.* (2001) also observed that HGM animals mobilised significantly more body fat in early lactation than lower-genetic-merit animals, which had a negative effect on submission and conception rates. These results emphasise that selection for high milk yields has lead to cows which experience a greater negative energy balance in early lactation (Knight *et al.*, 1999), a difference which may contribute to the lower fertility now exhibited in New

TABLE 1: Daily milksolids yields, estimated breeding value (EBV) for milksolids, lactation yield for milksolids, EBV for Lwt, and Lwt of high genetic merit (HGM) and low genetic merit (LGM) Jersey cows.

	HGM	LGM	SED	Significance
Daily milksolids production (kg/cow)				
Early lactation	1.59	1.46	0.026	***
Peak lactation	1.48	1.35	0.019	***
Mid lactation	1.48	1.32	0.017	***
Late Lactation	1.11	0.98	0.018	***
Lactation yields				
Milksolids EBV (kg/cow)	28.3	10.8	1.26	***
Milk solids (kg/cow)	327	288	6.8	***
Lactation length (days)	255	253	3.4	NS
Lwt (kg/cow)				
Lwt EBV	-42	-48	2.1	**
Early lactation	384	372	5.9	*
Peak lactation	385	375	5.5	NS
Mid lactation	404	393	5.2	*
Late Lactation	410	396	5.3	**

TABLE 2: Metabolisable energy intakes (MEI), and proportion of energy partitioned to lactation (EP_l), maintenance (EP_m), and Lwt change (EP_g) of high genetic merit (HGM) and low genetic merit (LGM) Jersey cows.

	HGM	LGM	SED	Significance
Early lactation				
MEI (MJ/cow/day)	157	151	2.7	*
EP_m	0.38	0.38	0.008	NS
EP_l	0.67	0.63	0.013	**
EP_g	-0.05	-0.01	0.019	*
Peak lactation				
MEI (MJ/cow/day)	166	155	1.9	***
EP_m	0.36	0.38	0.005	**
EP_l	0.59	0.57	0.008	*
EP_g	0.05	0.05	0.011	NS
Mid lactation				
MEI (MJ/cow/day)	166	152	1.8	***
EP_m	0.37	0.40	0.005	***
EP_l	0.58	0.56	0.007	**
EP_g	0.05	0.04	0.009	NS
Late lactation				
MEI (MJ/cow/day)	139	127	1.9	***
EP_m	0.46	0.49	0.008	***
EP_l	0.54	0.51	0.009	**
EP_g	0.00	0.00	0.013	NS

TABLE 3: The proportion of energy partitioned to lactation (EP_l) at each feeding level of high genetic merit (HGM) and low genetic merit (LGM) Jersey cows.

Level of feeding	High	Medium	Low	Very Low
Early lactation				
HGM	0.71 ± 0.017^a	0.70 ± 0.015^a	0.63 ± 0.023^b	0.62 ± 0.019^b
LGM	0.68 ± 0.024^a	0.67 ± 0.019^a	0.62 ± 0.015^a	0.55 ± 0.017^b
Peak lactation				
HGM	0.59 ± 0.011^a	0.62 ± 0.011^b	0.58 ± 0.015^a	0.58 ± 0.011^a
LGM	0.58 ± 0.014^{ab}	0.58 ± 0.012^{ab}	0.55 ± 0.009^b	0.59 ± 0.011^a
Mid lactation				
HGM	0.57 ± 0.008^a	0.57 ± 0.008^{ab}	0.58 ± 0.012^{ab}	0.60 ± 0.009^b
LGM	0.57 ± 0.011^{ab}	0.54 ± 0.009^a	0.55 ± 0.007^a	0.58 ± 0.009^b
Late lactation				
HGM	0.53 ± 0.010^a	0.52 ± 0.010^a	0.54 ± 0.016^{ab}	0.56 ± 0.015^b
LGM	0.55 ± 0.014^a	0.49 ± 0.012^b	0.49 ± 0.010^b	0.51 ± 0.013^{ab}

[abc]means within rows with different superscripts are significantly different (P<0.05)

Zealand herds (Holmes, 2001).

In this study, MEI were estimated using Lwt data, milk yields and composition, and energy concentrations of pasture, and were not actual measurements of intake and energy balance by indirect calorimetry. However, Agnew and Yan (2000) have demonstrated that the equations used in this study can be used to accurately predict the ME requirements for maintenance, lactation and Lwt change in grazing dairy cows. In addition, the present estimated values are generally consistent with published measured values (Oldenbroek, 1986; Yan *et al*., 2002). The present conclusion, that HGM grazing cows partition a greater proportion of dietary energy to milk than LGM cows, is also consistent with results based on measured feed intakes by non-grazing cows (Grainger *et al*., 1985).

Over the whole lactation, cows at the highest feeding level partitioned a higher proportion of MEI to milk than cows at the lowest feeding level (0.60 vs 0.57, respectively). In early lactation, HGM cows at the highest feeding level partitioned a significantly higher proportion of MEI to milk than HGM cows at the lowest feeding level (0.71 vs 0.62 for high and very low feeding levels, respectively; Table 3). Likewise, the difference between the high and very low feeding levels was highly significant (P<0.001) for the LGM cows in early lactation (0.68 vs 0.55, respectively). The same consistent trend was not observed in peak or mid lactation in either HGM or LGM cows.

In late lactation there was a significant (P<0.05) reduction in the proportion of energy partitioned to milk by LGM cows at medium and low feeding levels (P=0.08 at very low feeding levels) compared to the EP_l for LGM cows at the highest feeding level (Table 3). The same relationship was not observed in the HGM cows in late lactation. This data suggests very low feeding levels lead to a reduction in the level of partitioning of MEI into milk during early lactation and late lactation for LGM cows. Cows in early lactation compensated for low intakes by reducing the level of MEI partitioned to milk, which probably prevented excessive weight losses. LGM cows fed at low levels during late lactation partitioned more energy to maintenance of Lwt compared to HGM cows, resulting in lower persistency of milk production.

The cow's ability to partition total dietary energy between maintenance, milk and Lwt change is likely to affect their ability to partition extra dietary energy into milk (the marginal response to extra feed). This has been reported in a second paper (Bryant *et al.*, 2003), which shows an increase in genetic merit has a larger effect on actual milksolids yield at higher levels of feeding compared to lower levels of feeding. This is a form of genotype by environment interaction that has important practical implications for dairy farm systems.

While Jersey dairy cows were used in this trial, different results may have been obtained with Holstein-Friesian cows. For example, Mackle *et al.* (1996) found Jersey heifers partitioned more energy to milk during the lactation than Holstein-Friesian heifers (43% vs 37%, respectively). Thomson *et al.* (2001) and Oldenbroek (1986) observed that Jersey cows in early lactation utilised a higher proportion of their energy intake for milk production than Holstein-Friesian cows, although this advantage declined as the lactation proceeded.

ACKNOWLEDGEMENTS

JB would like to acknowledge the funding provided by AGMARDT, Dexcel, and the New Zealand Large Herds Association throughout his studies.

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