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Nutritional and physiological studies of differences between Friesian cows of high and low genetic merit

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ABSTRACT

The results of experiments with Friesian cows with breeding indices of 126 (HBI) or 102 (LBI) are presented. HBI cows produced an average of 153 kg milkfat/cow in the 1979 to 1981 lactations and LBI cows produced 125 kg milkfat/cow. HBI cows lost 0.7 of a condition score during lactation whereas LBI cows maintained their condition score. In 2 of the 4 stall feeding experiments the dry matter intake of pasture/kg$^{0.75}$ was significantly higher for HBI cows than LBI cows. There were no differences between the 2 groups of cows in their ability to metabolise dietary energy, nor in their heat production. HBI cows partitioned a greater proportion of their dietary energy to milk energy than LBI cows.

Blood samples taken hourly for 24 h periods from cows fed indoors were analysed for growth hormone, insulin, glucose, β-OH butyrate, and non-esterified fatty acids. Some of the animals also received glucose infusions. Differences between BI groups for levels of individual metabolites and hormones were observed and these differences varied depending on the level of feeding. Milk flow measurements were made on 5 occasions during the 1981/2 season. HBI cows despite higher milk yields, milked out more rapidly than LBI cows because of a higher maximum milk flow rate.

Keywords Friesian cows; breeding index; milk fat production; condition scores; energy balances; blood metabolites and hormones; milking rates

INTRODUCTION

The genetic merit of dairy cows in New Zealand for milk or milkfat production is indicated by their breeding index (BI), which shows the relative genetic merit of a cow to produce milk or milkfat in comparison to a baseline of 100, representing the average cow in the early 1960s. The selection programme carried out by the Farm Production Division of the New Zealand Dairy Board has achieved an increase in the average BI of the New Zealand dairy herd, which has certainly resulted in an increased production per cow (Wickham *et al.*, 1978). However the efficiency with which this increased production is obtained from pasture has not been measured, nor have the physiological mechanisms by which high BI cows produce more milk been identified.

This is a report on a series of experiments, commencing in spring 1979 at Massey University, comparing Friesian cows differing in BI with the objectives of measuring their ability to convert pasture to milk and of seeking physiological differences. Similar work with Jersey cows was begun at the same time at Ruakura Agricultural Research Station (Bryant and Trigg, 1981).

METHODS

A total of thirty-six 3 or 4 year old Friesian cows, 19 with a mean BI of 126 (HBI) and 17 with a mean of 102 (LBI) were identified by the Farm Production Division of the New Zealand Dairy Board and were purchased from farmers mainly in the Wairarapa, Manawatu and Taranaki regions.

Experiments were carried out to determine the performance of the cows when grazing or when fed cut pasture in stalls. Four stall-feeding experiments were carried out in which pasture was fed for periods of 28 days to 20 cows. Experiments 1, 2 and 3 were carried out in 1979/80 and began 28, 80 and 150 days after calving respectively. Experiment 4 was carried out in 1980/1 and began 80 days after calving. In Experiment 1 all cows were fed pasture *ad libitum* and in the remaining experiments, including Experiment 4, half the cows were fed pasture *ad libitum* and half were restricted to 70% *ad libitum*.

Full energy balances were measured with 3 cows of HBI (127) and 3 cows of LBI (101) during the second and third month of lactation and again during the seventh month of lactation. Measurements on each cow were made at 2 levels of feeding, *ad libitum* and approximately 70% *ad libitum*. Indirect calorimetric techniques were used and the cows were fed freshly-cut pasture. Full energy balances were also measured with 4 non-lactating cows of HBI (128) and 4 non-lactating cows of LBI (100) during the seventh and eighth month of pregnancy. Four of the cows were fed at approximately maintenance and 4 were fed approximately 1.8 times maintenance. Each cow remained on the level of feeding for a period of 62 days, and 2 energy balances were measured for each cow. Details of all methods can be obtained from Grainger (1982). In all experiments the pasture consisted mainly of perennial ryegrasses and white clover with appreciable amounts of red clover in Experiments 3 and 4.

At the end of Experiment 4, 18 blood samples were taken over a 24 h period from 9 HBI cows and 7 LBI cows, each fitted with a jugular catheter. On the next 2 days some of the cows were infused with 20 g glucose in 400 ml of saline over a period of 20 minutes commencing at 11 a.m. On day 1, 2 HBI and 2 LBI cows were infused with glucose plus saline and 2 HBI and 1 LBI cows were infused with saline only. For day 2 the treatments were reversed. Blood samples were taken immediately prior to infusion and 0.5, 5, 10, 20, 40, 90 and 180 minutes after infusion stopped. All blood samples were analysed for glucose, β-OH butyrate, non esterified fatty acids (NEFA), insulin and growth hormone.

Rates of milking were measured on 5 occasions at morning and evening milkings over a complete lactation for 18 HBI and 16 LBI cows in the 1981/2 season. The volume of milk in the flasks of the milk meter was measured every half minute from the time the cups were put on until they were removed by automatic cup removers. Maximum flow rates were calculated by measuring the slope of the linear portion of the graph obtained by plotting accumulated milk volumes against time.

RESULTS AND DISCUSSION

Feeding Experiments and Performance of the Cows

The performance of the cows in the 1979/80 and 1980/1 seasons is summarised in Table 1. The HBI cows produced 28% and 18% more milkfat than the LBI cows respectively. Both groups of cows were in similar condition at calving in both seasons, but HBI cows lost condition, whereas LBI cows maintained body condition during the lactation. Milkfat productions in both years were not high. This is attributed partly to the fact that all cows were 3-year-olds in 1979/80 and to the periods of restricted feeding indoors in both years. The milkfat yields of the 4-year-old HBI and LBI cows not involved in the indoor experiments in 1980/1 were 175 and 144 kg/cow respectively.

TABLE 1 Milkfat production, live weights and condition scores of high and low breeding index Friesian cows.

	1979/80			1980/1		
	HBI	LBI	SE difference	HBI	LBI	SE difference
No. cows	10	10		19	17	
Breeding index	127	100	1.4	126	102	1.2
Length of lactation (d)	260	256	5.3	238	233	3.2
Milkfat yield/cow (kg)	150	117	8.0	158	133	6.8
Milkfat (%)	4.58	4.22	0.18	4.50	4.36	0.15
Live weight at calving (kg)	383	411	16	389	421	20
Condition score at calving	4.7	4.7	0.14	4.7	4.9	0.17
Condition score at drying off	3.9	4.8	0.23	4.1	4.9	0.22

The milkfat productions of HBI and LBI cows at different stages in lactation are summarised in Table 2.

TABLE 2 Milkfat yields of high and low breeding index cows at different stages of lactation (kg/cow/d).

	1979/80			1980/1		
	Stage of lactation (d)					
	30	150	240	30	150	210
Milkfat yields (High)	0.66	0.59	0.55	0.90	0.59	0.42
Difference in milkfat yield (High-Low)	0.11	0.14	0.20	0.09	0.09	0.06
SE of difference	0.04	0.03	0.05	0.05	0.03	0.03

Absolute differences in milkfat production between the 2 groups of cows increased with stage of lactation in the 1979/80 season. If current milk yield had been used as a criterion for drying off, then the LBI cows would have had a shorter lactation than the HBI cows, but the reverse would have been true if a minimum condition of the cows had been used as a criterion.

In the second season (1980/1) changes in absolute differences in milkfat production did not follow the same pattern as the first lactation because differences between the 2 groups of cows were smaller at the end of lactation, compared with early and mid lactation.

There were no significant differences in the dry matter (DM) intake of pasture between HBI and LBI cows in any of the indoor feeding experiments. However, the LBI cows were consistently heavier than the HBI cows and metabolisable energy intakes per unit of metabolic weight were higher ($P < 0.10$) for HBI cows in Experiment 1 and in Experiment 3 ($P < 0.05$) (see Table 3). The mean intakes of pasture by cows receiving pasture *ad libitum* in the 4 indoor experiments, expressed as kg DM per 100 kg live weight were 3.8 and 3.5 for the HBI and LBI respectively. Feed conversion ratios for cows receiving pasture at the *ad libitum* level are also given in Table 3.

TABLE 3 Metabolisable energy intakes (MEI) and feed conversion ratios (FCR) for high and low breeding index Friesian cows fed pasture indoors.

	MEI ($MJ/kg^{0.75}/cow/d$)			FCR (kg DM/kg milkfat)	
Expt.	HBI	LBI	SE diff.	HBI	LBI
1	1.97	1.87	0.05	19.1	23.3
2	1.96	1.96	0.07	24.6	30.6
3	2.26	2.05	0.05	25.8	32.8
4	2.07	2.06	0.08	23.3	26.1

In all of the indoor experiments, HBI cows produced significantly more milkfat than LBI cows at the same DM or metabolisable energy intake.

Energy Metabolism

Lactating cows

Over the whole lactation, the 3 HBI cows produced 172 kg milkfat and lost 0.4 condition score, while the 3 LBI cows produced 132 kg milkfat and their condition score did not change. The live weights in early lactation were 377 and 432 kg for the HBI and LBI cows respectively. When fed *ad libitum*, the HBI cows ate 6 to 8% more pasture DM (15 to 28% more per unit of metabolic weight) than the LBI cows. The daily yields of milkfat were 1.10 kg and 0.97 kg/cow in early lactation for the HBI and LBI cows respectively.

TABLE 4 Mean values for the metabolisability of dietary energy by high and low breeding index Friesian cows (ME/GE).

Time	Level of feeding	HBI	LBI
Early	*Ad libitum*	0.63	0.64
lactation	Restricted	0.65	0.67
Late	*Ad libitum*	0.54	0.54
lactation	Restricted	0.53	0.52
Dry	1.8 × maintenance	0.61	0.62
period	maintenance	0.62	0.63

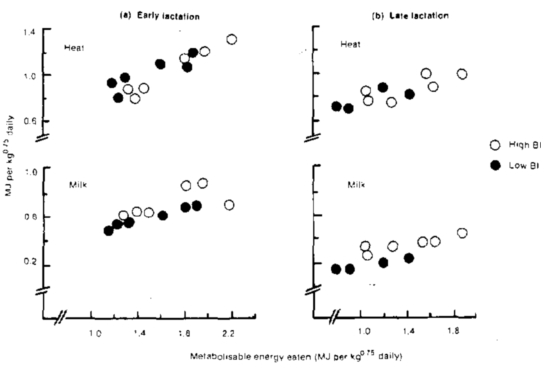

FIG. 1 Heat and milk energy produced by lactating cows.

There were no significant differences between the 2 groups of cows with respect to the losses of energy in faeces, urine and methane. The mean metabolisabilities of dietary energy are shown in Table 4. The data were subjected to multivariate or univariate analyses where appropriate (see Grainger, 1982). The comparisons between the 2 groups of cows discussed below refer to data adjusted to a common mean intake of metabolisable energy.

There were no significant differences in heat production due to BI, except at the lower level of feeding in early lactation when the HBI cows produced slightly less heat than the LBI cows (see Fig. 1). The HBI cows produced more milk energy than the LBI cows in both cases (0.06 and 0.11 MJ per $kg^{0.75}$ more per day in early and late lactation respectively) although the difference was significant only in late lactation. This indicated that, except at the lower level of feeding in early lactation, the HBI cows produced the same amount of heat, more milk energy and less body tissue energy than the LBI cows when fed on a given quantity of metabolisable energy.

Non-lactating cows

There were no significant differences due to BI in the energy losses in faeces, urine and methane or in heat (see Table 4 and Fig. 2).

The quantities of metabolisable energy required for maintenance of zero total energy retention (ME_m) and the net efficiency with which ME was utilised above maintenance (k) were calculated by regression analyses. Breeding index had no significant effect and the pooled values were 0.69 MJ ME per $kg^{0.75}$ daily and 0.52 for ME_m and k respectively.

Plasma Hormones and Metabolites

Differences in the concentration of hormones and metabolites in the plasma between the BI groups were

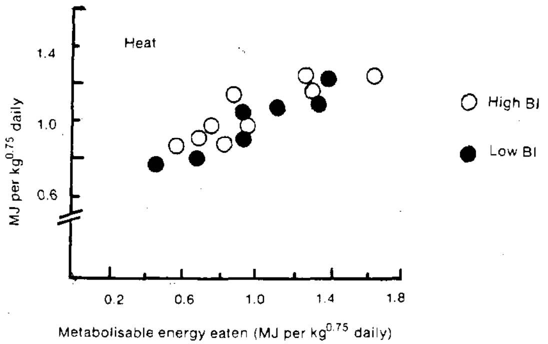

FIG. 2 Heat energy produced by dry cows.

most pronounced in the cows on the restricted plane of feeding. Thus the mean glucose concentration over the whole day for LBI cows was 59.9 mg/dl which was lower ($P < 0.05$) than the mean concentration for the HBI cows of 64.1 mg/dl, the latter value being not significantly different from the values for both groups fed to appetite. The mean concentration of insulin in the HBI group on restricted intake (938 pg/ml) was greater ($P < 0.01$) than that for the LBI group (340 pg/ml). The mean concentration of insulin for both groups fed to appetite was not significantly different from that of the LBI group on the restricted feeding.

These results for insulin and glucose clearly indicated differences between the BI groups on the restricted plane of feeding. There were smaller differences between groups for growth hormone, β-OH butyrate and NEFA. For example the mean concentrations of growth hormone were higher in the HBI cows than in the LBI cows on both planes of feeding although the differences were not statistically significant.

Because of the central role of glucose in milk synthesis, further studies of carbohydrate metabolism were carried out by infusing glucose. Following infusion, the increase in glucose and insulin concentrations were similar for both BI groups. Thus the concentrations of insulin and glucose, which were higher in the HBI cows prior to infusion, remained higher following infusion. Despite the high insulin concentration in the HBI cows, glucose concentrations did not fall at a greater rate than in the LBI cows. It appears that although the release of insulin was similar between the 2 BI groups, the removal of glucose was less sensitive to insulin concentration in the HBI cows. This would reduce glucose use by peripheral tissues and as a consequence increase the availability of glucose to the mammary gland.

Rates of Milking

The rate of milking was measured on 5 occasions over a lactation. On each occasion the maximum flow rate for the HBI cows was greater than that of the LBI cows. With the exception of the morning milking in September, all other differences were significant ($P < 0.05$). The mean maximum flow rates at morning and evening milkings combined were 2.21 and 1.64 l/min. for the HBI and LBI cows respectively. Consequently the LBI cows took approximately 15% longer to milk out despite their milk yields being 10% less than those of the HBI cows.

SUMMARY AND CONCLUSIONS

HBI cows consistently produced more milkfat than LBI cows and there was close agreement between expected differences based on breeding index and actual differences in milkfat yield. HBI cows lost condition over lactation whereas LBI cows maintained condition. There were no differences between HBI and LBI cows in their ability to metabolise dietary energy or in their heat productions. There was evidence, but it was not conclusive, that the food intake/kg$^{0.75}$ of HBI cows was greater than LBI cows. The main explanation for the higher milkfat production of the HBI cows lies in their ability to allocate a greater proportion of metabolisable energy towards milk energy and a smaller proportion to tissue energy, compared with LBI cows.

The differences between the BI groups in insulin and glucose indicated a greater availability of glucose to the mammary gland for the HBI cows compared with the LBI cows. Additional information on milking rate showed that flow rates were greater for HBI cows than for LBI cows.

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