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Total mixed rations versus pasture diets: Evidence for a genotype x diet interaction in dairy cow performance

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ABSTRACT

The performance of overseas (OS) and New Zealand (NZ) Holstein Friesian (HF) dairy cows were compared on an all-pasture diet (Grass) or a total mixed ration (TMR). Dietary treatments had been imposed for two years prior to the 2000/2001 season for which these results are reported. The four treatments were NZ Grass (n=14); OS Grass (n=13); NZ TMR (n=14); and OS TMR (n=14). Genotype x diet interactions were observed for annual milk yield, milksolids yield, efficiency of milksolids production, liveweight gain during lactation, and the proportion of cows not in calf. Measurement of individual cow intake using alkane markers during early, mid, and late lactation identified when these genotype x diet interactions occurred. When fed TMR, OS HF performed better than NZ HF, but on grass NZ HF performed better than OS HF. This has implications for the selection of sires for the national herd, and for the use of different dairy cow genotypes in different dairying systems.

Keywords: Holstein Friesian; genotype; diet; interaction.

INTRODUCTION

Genotype x environment interactions have been reported for pasture-based dairy cattle (Harris & Kolver, 2001; Peterson, 1991), but this is not always the case (Cromie *et al.*, 1997; Ferris *et al.*, 1999). During the last ten years, high use has been made in New Zealand of overseas Holstein Friesian (OS HF) genetics from North America and the Netherlands (Harris *et al.*, 1999). Evidence for an interaction would have significant implications for national breeding objectives as this would mean that ranking of bulls would change depending on the dairying system their progeny were farmed in.

A comparison of milk production proofs of Canadian sires tested in New Zealand with their original home proofs concluded that proofs made in Canada were not reliable predictors of progeny performances in New Zealand conditions (Peterson, 1991). This difference in ranking of sires suggested the existence of a genotype x environment interaction. However, analysis of the performance of high-genetic-merit heifers of North-American origin in commercial herds in Ireland (Cromie *et al.*, 1997), and in high- and low-input feeding systems at Hillsborough, Ireland (Ferris *et al.*, 1999), and Moorepark, Ireland (Dillon & Buckley, 1998) found no such genotype x environment interaction. These studies clearly indicated that heifers of high genetic merit and North-American genetics produced more than medium-genetic-merit heifers of Irish ancestry in low-input grass systems, albeit at lower levels of production than in high-input systems. The grass-based low-input system in the Moorepark comparison, however, still included 500 kg DM/cow/year of concentrate and 400 kg N/ha at a stocking rate of 2.54 cows/ha.

Kolver *et al.* (2000) reported a genotype x diet interaction for liveweight gain in heifers during the first year of a trial comparing New Zealand Holstein Friesians (NZ HF) and OS HF of similar Breeding Worth (BW) fed either grazed pasture or a total mixed ration.

This paper reports the third year of the study described by Kolver *et al.* (2000), with particular emphasis on

measures of productive efficiency during the lactation period.

MATERIALS AND METHODS

Design

Genotype, diet, and genotype x diet interactions were investigated during the third year of a four-year experiment that compared HF genetics of New Zealand (NZ) or OS origin. Primiparous and multiparous OS and NZ HF either grazed pasture (Grass) or were fed a total mixed ration (TMR) at the Dexcel No. 1 Dairy during the 2000/2001 season. The four treatments in this 2 x 2 factorial experiment were NZ Grass (n=14); OS Grass (n=13); NZ TMR (n=14); and OS TMR (n=14). During the first year animals consisted of all heifers, with an equal proportion of heifers entering each of the treatment groups in subsequent years. During the 2000/2001 season the age distribution within each treatment was three first-lactation, three second-lactation, and eight third-lactation cows. An exception was the OS Grass treatment that included seven cows in third lactation. Each year, heifers entering the treatment groups were paired within genotype and randomly allocated to treatment. Heifers entering the dietary treatment groups each year were balanced for BW and, within genotype, treatments were balanced for sire and liveweight. Being the third year of the experiment, multiparous cows differed in liveweight at the start of 2000/2001. In 2000/2001 all treatments had a similar mean calving date (27 July \pm 21 d, NZ Grass; 17 July \pm 18 d, NZ TMR; 20 July \pm 25 d, OS Grass; 11 July \pm 21 d, OS TMR; mean \pm SD), and had similar days in milk (DIM).

Cow selection

During the first year of the study eight sires were represented in the OS treatments and seven sires were represented in the NZ treatments. The OS genotype had 100% OS ancestry; 10 of the 20 OS heifers originated from the United States and 10 of the 20 OS heifers originated from the Netherlands. Holland Genetics Ltd.

imported the OS genetics into New Zealand in 1996 as embryos for the Livestock Improvement Corporation (LIC) as part of the LIC Sire-Proving Scheme. As such, the OS genetics used in the present experiment represent OS genetics that have been used in NZ. After birth, OS calves were sold to commercial farmers and were subsequently purchased by Dexcel prior to their first parturition. Heifers entering treatment groups in the second year were purchased as 6-12 month heifers, and in the third year were purchased prior to parturition. The NZ genetics used in the present experiment were selected from Dexcel herds based on BW and proportion of NZ ancestry. The NZ heifers had less than 12.5% OS genes and had a BW comparable to the OS heifers. By the third season (2000/2001) the same sires were represented across treatments, within genotype, with the following number of sires in each treatment group: 7 NZ Grass; 8 NZ TMR; 8 OS Grass; 12 OS TMR.

The OS HF represented sires that were widely used in the New Zealand national herd. At the initiation of the experiment, half of the OS sires had been proven in New Zealand, and half of the OS sires had relatives that had been proven in New Zealand. Of these sires, all now have New Zealand proofs. In addition, the brothers of the heifers used in this experiment were part of the LIC's Sire-Proving Scheme.

Feeding and management of TMR cows

Cows fed TMR were confined to one of five loafing paddocks (0.25 ha/paddock) and a free-draining concrete and post-peelings feedpad which was sheltered from the wind (288 m²; 11.5 m² per cow). NZ and OS HF were maintained in separate herds throughout lactation. The feedpad was used during July, August and September and the loafing paddocks for the rest of lactation. The TMR was fed between 0800 and 1000 h and between 1500 and 1700 h each day in four 5-m mobile fibreglass troughs. NZ HF and OS HF received the same TMR and were fed to achieve a 10% refusal rate (*ad libitum* intake). The feeds were weighed and mixed daily using a Jaylor vertical mixer wagon and fed separately to the NZ and OS TMR groups. During the dry period, cows were maintained on pasture and were introduced onto a pre-calving TMR 20 days prior to expected calving date (Roche *et al.*, 2002).

The criteria used to formulate the TMR were to maintain a ration supplying nutrients and to use feed ingredients that were typical of the diets fed in North

America or Europe in systems within which the OS genetics were selected. The TMR was not a least-cost ration, but a standard control. Cows were fed according to NRC (1989) dairy cow feed requirements for high production. Rations were formulated using the Spartan ration formulation programme (Van de Haar *et al.*, 1992) and the Cornell Net Carbohydrate and Protein System model (Fox *et al.*, 1992). The TMR consisted of forage and concentrates in the proportions described in Table 1. The pelleted concentrate (10 mm in length) was formulated to balance nutrients supplied by the forages and whole cottonseed. During early lactation, the concentrate comprised 40.7% ground maize grain, 22.5% soybean meal, 8.6% barley grain, 6.4% molasses, 4.8% corn gluten meal, 5.7% fishmeal, 4.3% soyoil, 2.1% calcium di-phosphate, 1.5% limeflour, 1.1% rumen-protected fat, 0.4% salt, 0.5% urea, 0.3% magnesium oxide, 1.0% sodium bicarbonate, and 0.05% ruminant trace mineral and vitamin pre-mix (% concentrate DM). During mid-late lactation the concentrate comprised 38.3% ground maize grain, 5.6% soybean meal, 27.1% barley grain, 6.9% molasses, 10% corn gluten meal, 6.1% fishmeal, 1.4% soyoil, 1.7% di-calcium phosphate, 0.9% limeflour, 0.3% salt, 0.2% urea, 0.3% magnesium oxide, 1.1% sodium bicarbonate, and 0.05% ruminant trace mineral and vitamin pre-mix (% concentrate DM).

Grazing management

The grazing cows were generously fed throughout lactation, i.e., an allowance of greater than 60 kg DM/cow/d was offered. This experiment did not test NZ and OS HF in a confined pasture system. Rather, cows were offered paddocks at No. 1 Dairy (total area 60 ha) for grazing and were followed by a non-treatment herd of cows or pasture was topped to maintain pasture quality. For most of the season, however, cows remained on 10 ha (2.7 cows/ha; approximately 80 kg LW/tDM), grazing pastures every 14-16 days in spring and 20 days in summer and autumn. Post-grazing residuals were used to determine pasture allocation; post-grazing residuals of greater than 1800 kg DM/ha were targeted during spring and autumn and greater than 2200 kg DM/ha during summer. A small amount of silage was offered to both herds during spring (2 weeks) and summer (3 weeks) at a rate of 0.5% of liveweight to maintain pasture residual targets. Both NZ Grass and OS Grass herds grazed the same paddock but were separated by a wire to allow calculation of herd intake. The decision to dry off was based on condition score and daily milk production. Grazing cows received 12 g supplementary magnesium/cow/d in the water trough pre-calving and as a drench post calving.

Measurements

Milk yield was recorded daily and milk composition determined weekly from a 30-ml subsample. Liveweight was recorded weekly and body condition score every second week. A representative 500-g sample of the feeds used in the TMR, refused TMR, and pre-grazed pasture was collected on one day each week. Samples were oven-dried at 100 °C for determination of DM, and at 60 °C for

TABLE 1: Proportion (% dietary DM) of maize silage, grass silage, hay, whole cottonseed, and concentrate in the total mixed ration during the 2000/2001 lactation.

	Stage of lactation ¹			
	Late Dry	Early	Early-mid	Mid-late
Maize silage	40	25	25	18
Grass silage	19.2	19.5	21	35
Hay	10.8	7.5	2	2
Whole cottonseed	6	10	10	8
Concentrate	24	38	42	37

¹Late dry: 3 weeks prior to expected calving (June and July); Early lactation: Calving until 11 August 2000; Early-mid lactation: 11 August 2000 to 23 February 2001; Mid-late lactation: 23 February to 15 May 2001.

subsequent near-infrared analysis (NIRS systems 6500) and chemical analysis of nutrient composition (Kolver and Muller, 1998).

Individual intake periods

Individual cow intake was measured at three times during lactation (September, 57 ± 22 DIM; December, 141 ± 22 DIM; and March, 228 ± 22 DIM; mean \pm SD) using alkane markers (Dove & Mayes, 1991). Cows were orally dosed with alkanes twice a day for 10 days. Faecal samples were collected twice a day during the last 5 days of alkane dosing. Samples of pasture and TMR offered and refused were collected in triplicate on the 5 days corresponding to intake measurement, oven-dried at 100 °C for determination of DM, and at 60 °C for subsequent near-infrared and chemical analysis of nutrient composition. Cows were weighed weekly and condition scored fortnightly during the experimental period.

Statistical analysis

Data were analysed using the residual maximum likelihood (REML) procedure of Genstat (Version 3.2) according to completely randomised design. The model included age, genotype, diet, and interactions as fixed effects and sire as a random effect. Significant effects were declared at $P < 0.05$ and trends at $P < 0.10$.

RESULTS

The nutrient composition of the pasture was consistent with high quality herbage (Table 2). Nutrient levels of the TMR met levels recommended by NRC (1989) for dairy cows of high production. The TMR contained less crude protein (CP), neutral detergent fibre (NDF), and more non-fibre carbohydrate (NFC) than pasture during the season. Both diets had a similar mean ME content.

TABLE 2: Mean annual nutrient composition of the grass diet¹ and total mixed ration (TMR)² during the 2000/2001 lactation.

	Grass	TMR
ME (MJME/kg DM)	11.7	11.8
Crude protein (%DM)	26.9	18.2
Degradable protein (% Protein)	57.8	56.2
Soluble protein (% Protein)	30.8	33.1
Neutral detergent fibre (%DM)	42.5	34.3
Acid detergent fibre (%DM)	23.3	21.0
Non fibre carbohydrate (%DM)	16.1	36.3
Fat (%DM)	4.2	6.7
Ash (%DM)	10.3	7.9
Calcium (%DM)	0.60	0.74
Phosphorous (%DM)	0.32	0.53
Magnesium (%DM)	0.19	0.24
Potassium (%DM)	3.03	1.54
Sodium (%DM)	0.27	0.36
Chlorine (%DM)	0.91	0.66
Sulphur (%DM)	0.33	0.20
Iron (mg/kgDM)	193	359
Zinc (mg/kgDM)	65	47
Copper (mg/kgDM)	6	11
Selenium (mg/kgDM)	0.55	0.49
Manganese (mg/kgDM)	59	63
Molybdenum (mg/kgDM)	<1	<1

¹Cows received additional copper, selenium, and magnesium supplements.

²Includes vitamin premix (5 kIU/kgDM Vitamin A, 0.5 kIU/kgDM Vitamin D, 13 kIU/kgDM Vitamin E).

All treatments had similar DIM (Table 3). OS HF produced more milk with a lower milkfat and protein content, had a higher liveweight, gained less liveweight during lactation, ended the lactation with a lower body condition score, and had a higher empty rate compared to NZ HF. OS HF tended to produce more milksolids than NZ HF.

Compared to cows fed Grass, cows fed TMR produced more milk and milksolids, had a lower milkfat content, and were more efficient producers of milksolids (Table 3). Cows fed TMR also gained more liveweight during lactation than cows fed Grass, and ended lactation with a greater liveweight and body condition score. Diet did not influence milk protein content or empty rate.

A genotype x diet interaction was observed for milk yield, milksolids yield, efficiency of milksolids production, liveweight gain during lactation, and empty rate (Table 3). The nature of this interaction was generally in favour of OS HF on TMR, and in favour of NZ HF in the Grass treatment.

In early lactation, OS HF had a greater liveweight, and similar milksolids yield, intake (%LW) and efficiency (kgDM/kgMS; MJME/kgMS) compared to NZ HF (Table 4). OS HF tended to have a higher intake (kgDM/d) and a lower efficiency of milksolids production (gMS/kgLW^{0.75}) compared to NZ HF. Cows fed TMR had a greater milksolids yield, liveweight, intake, efficiency of milksolids production (gMS/kgLW^{0.75}), but similar efficiency (kgDM/kgMS; MJME/kgMS) compared to cows fed Grass. A genotype x diet interaction was observed for intake (kgDM/d). A trend for an interaction was observed for milksolids yield and efficiency (gMS/kgLW^{0.75}).

In mid lactation, OS HF had a greater liveweight, intake (kgDM/d), lower efficiency (kgDM/kgMS; MJME/kgMS) and similar intake (%LW) and efficiency (gMS/kgLW^{0.75}) than NZ HF (Table 4). OS HF tended to have a higher milksolids yield than NZ HF. Cows fed TMR had greater milksolids yield, liveweight, intake (kgDM/d) and efficiency (gMS/kgLW^{0.75}; DM/kgMS; MJME/kgMS) than cows fed Grass. A genotype x diet interaction was observed for milksolids yield and efficiency (gMS/kgLW^{0.75}; DM/kgMS), and a trend for an interaction for intake (kgDM/d).

In late lactation, OS HF produced more milksolids, had a greater liveweight and intake (kgDM/d), and similar intake (%LW) and efficiency (gMS/kgLW^{0.75}; DM/kgMS; MJME/kgMS) compared to NZ HF (Table 4). Cows fed TMR had a greater milksolids yield, liveweight, intake, and efficiency (gMS/kgLW^{0.75}; DM/kgMS; MJME/kgMS) compared to cows fed Grass. A genotype x diet interaction was observed for milksolids yield, intake (kgDM/d), and efficiency (gMS/kgLW^{0.75}), and a trend for an interaction for intake (%LW).

DISCUSSION

This study has identified genotype x diet interactions between OS HF and NZ HF grazing pasture or fed TMR for milk yield, milksolids yield, efficiency of milksolids production (kgMS/kgLW^{0.75}), liveweight gain during lactation, and empty rate. At points during lactation

TABLE 3: Mean annual milk production, efficiency of milksolids production, liveweight and body condition score of New Zealand (NZ) and overseas (OS) Holstein Friesians grazing pasture (Grass) or fed total mixed ration (TMR) during the 2000/2001 lactation.

Genotype (G) Diet (D)	NZ		OS		SED	Genotype	P Diet	G x D
	Grass	TMR	Grass	TMR				
Annual production								
Days in milk	300	300	298	298	4.1	0.851	0.952	0.985
Milk yield (kg/cow)	5300	7304	5882	10097	300.5	<0.001	<0.001	0.003
Milkfat (%)	5.03	4.60	4.28	3.62	0.231	<0.001	<0.001	0.352
Milk protein (%)	3.74	3.65	3.50	3.54	0.081	0.043	0.232	0.547
Milksolids (kg/cow)	465	602	459	720	22.3	0.082	<0.001	0.041
Efficiency (kg MS/kg LW)	0.94	1.08	0.81	1.14	0.072	0.164	<0.001	0.011
Efficiency (kg MS/kg LW ^{0.75})	4.42	5.26	3.97	5.72	0.572	0.147	<0.001	0.032
Liveweight and body condition								
Mean LW (kg/cow)	495	556	565	634	28.3	<0.001	<0.001	0.438
Gain during lactation (kg/cow)	44	92	-20	77	15.2	0.042	<0.001	0.039
Gain during lactation (%LW)	8.89	16.55	3.54	12.15	1.702	<0.001	<0.001	0.081
Season end (kg/cow)	532	624	561	684	17.8	0.003	<0.001	0.674
Season end condition score	5.0	7.6	4.6	6.1	0.03	0.004	0.012	0.732
Reproduction								
Empty rate (%)	7 (1 cow)	14 (2 cows)	62 (8 cows)	29 (4 cows)	12.3	0.042	0.104	0.023

TABLE 4: Mean milksolids production, liveweight, dry matter intake, and efficiency of milksolids production of New Zealand (NZ) and overseas (OS) Holstein Friesians grazing pasture (Grass) or fed total mixed ration (TMR) during early, mid, and late lactation 2000/2001.

Genotype (G) Diet (D)	NZ		OS		SED	Genotype	P Diet	G x D
	Grass	TMR	Grass	TMR				
Early lactation								
Milksolids (kg/d)	2.02	2.42	1.92	2.61	0.121	0.617	<0.001	0.089
Liveweight (kg)	470	512	536	597	24.7	0.003	<0.001	0.334
Intake (kg DM/d)	16.6	20.4	17.3	24.0	1.33	0.070	<0.001	0.034
Intake (% LW)	3.57	4.01	3.26	4.07	0.226	0.622	<0.001	0.131
Efficiency (g MS/kg LW ^{0.75})	19.9	22.4	17.0	22.0	1.11	0.092	<0.001	0.083
Efficiency (kg DM/kg MS)	8.52	8.68	9.47	9.25	0.624	0.179	0.986	0.549
Efficiency (MJME/kg MS)	108.3	104.3	118.3	111.0	7.60	0.219	0.150	0.675
Mid lactation								
Milksolids (kg/d)	1.48	2.05	1.43	2.40	0.114	0.076	<0.001	0.011
Liveweight (kg)	498	553	558	629	21.4	0.001	<0.001	0.497
Intake (kg DM/d)	16.1	18.2	17.9	21.7	0.75	<0.001	<0.001	0.091
Intake (% LW)	3.24	3.32	3.26	3.44	0.184	0.626	0.258	0.604
Efficiency (g MS/kg LW ^{0.75})	14.1	18.2	12.4	19.2	0.967	0.696	<0.001	0.046
Efficiency (kg DM/kg MS)	11.00	9.10	12.97	9.34	0.561	0.018	<0.001	0.030
Efficiency (MJME/kg MS)	122.1	108.4	138.7	111.2	6.19	0.045	<0.001	0.112
Late lactation								
Milksolids (kg/d)	1.23	1.69	1.24	2.19	0.132	0.014	<0.001	0.010
Liveweight (kg)	489	601	549	668	20.1	0.002	<0.001	0.743
Intake (kg DM/d)	14.4	18.1	15.9	22.0	0.60	<0.001	<0.001	0.004
Intake (% LW)	2.96	3.04	2.92	3.32	0.138	0.267	0.014	0.075
Efficiency (g MS/kg LW ^{0.75})	11.9	14.1	10.9	16.7	1.18	0.336	<0.001	0.025
Efficiency (kg DM/kg MS)	11.87	11.36	13.21	10.55	0.961	0.711	0.024	0.107
Efficiency (MJME/kg MS)	132.9	132.9	146.6	123.4	11.11	0.800	0.149	0.132

interactions have also been detected for intake and efficiency of milksolids production (kgDM/kgMS).

These results are important because they suggest that the ranking of bulls used by the national herd may change depending on the dairying system in which their progeny are farmed. Because this study made the unique comparison of two HF genotypes of the same initial BW, observed differences can be attributed largely to genotype differences rather than genetic merit *per se*.

Dillon & Buckley (1998) did not observe a genotype x diet interaction when high-genetic-merit North American HF were compared with medium-genetic-merit Irish HF and fed 0.9 or 1.5 t DM/cow/year of concentrates. However, daughters of Canadian and New Zealand sires farmed in both Canadian and New Zealand management systems demonstrated significant differences in ranking of sires for yield traits (Peterson, 1991). When farmed in

the New Zealand environment, daughters of Canadian sires had lower survival rates, while daughters of New Zealand sires had higher culling rates than their Canadian contemporaries in the Canadian farming system (Mwansa & Peterson, 1998).

The observation of genotype x diet interactions in the current study, may be a result of using diets that provided a greater difference in nutrient supply than the diets compared in the study of Dillon & Buckley (1998). Veerkamp *et al.* (1994) discussed the possibility that high-genetic-merit dairy cows may not be able to maintain their genetic advantage under a low-input system as the increase in gross energetic efficiency of high-genetic-merit dairy cows is not due to better utilisation of feed, but rather to a higher degree of body tissue catabolism and to simple dilution of maintenance. If there was a limit to the rate of tissue mobilisation or the amount of mobilisable tissue, a

genotype \times environment interaction may occur. Because tissue reserves are substantial, Veerkamp *et al.* (1994) suggested that the use of these reserves in one lactation might buffer high-merit animals against nutritional adversity and so diminish interactions in the short term, these only becoming evident in subsequent years. In the present study, both genotypes in the grazing treatment calved at the same condition score (5.5 on a 1 to 10 scale). The interactions observed suggest that the tissue reserves of OS HF may not be sufficient to prevent subsequent reductions in fertility and survival, even when *ad libitum* amounts of high quality pasture is available.

In the present study, when cows were generously fed on pasture and stocked at approximately 80 kg liveweight/t DM, OS HF were significantly less likely to get in calf, gained less liveweight during lactation (% LW), were less efficient at producing a kilogram of milksolids (kgMS/kgLW^{0.75}), and produced more milk yield, but similar milksolids yield compared to NZ HF. When fed TMR, OS HF had the same reproductive performance, gained less (but adequate) liveweight during lactation (%LW), were more efficient at producing a kilogram of milksolids (kgMS/kgLW^{0.75}), and produced more milk yield and milksolids than NZ HF.

An examination of the treatments that appeared to be responsible for the genotype \times diet interaction showed that the genotype \times diet interaction for milksolids yield occurred primarily because OS TMR produced more than NZ TMR; the genotype \times diet interaction for efficiency of milksolids production (kgMS/kgLW^{0.75}) occurred because OS Grass were less efficient than NZ Grass, and OS TMR were more efficient than NZ TMR; the genotype \times diet interaction for liveweight gain during lactation occurred primarily by OS Grass gaining less weight (% LW) than NZ Grass; and the genotype \times diet interaction for empty rate occurred primarily because OS Grass were more difficult to get in calf than NZ Grass.

The reasons for these genotype \times diet interactions may be found in the results from early, mid, and late lactation. Of particular interest are the changes in the relative differences between OS HF and NZ HF on the respective diets as lactation progressed. As a general observation, genotype \times diet interactions became more statistically significant as lactation progressed.

During early lactation greater differences in efficiency (kgMS/kgLW^{0.75}) between the genotypes appeared to occur on the pasture diet rather than TMR, as OS Grass were less efficient than NZ Grass. This was probably a result of a numerically lower intake (%LW). By late lactation, a large difference in efficiency was apparent between OS TMR and NZ TMR, rather than between the two genotypes fed pasture. These differences in late lactation were probably related to the higher intake (%LW) of OS TMR relative to NZ TMR and the comparatively smaller differences in intake (%LW) between the two genotypes grazing pasture. An interaction for efficiency (kgDM/kg MS; MJME/kgMS) may also have been a factor in late lactation, although significance was not reached (P=0.107 and P=0.132, respectively). It must be noted that the estimates of efficiency (kg DM/kg MS; MJME/kg MS) are overall measures of efficiency

and include energy associated with liveweight gain and loss. As such, differences in efficiency are the net product of differences in intake and liveweight gain/loss.

The productive (and reproductive) problems encountered by OS HF grazing pasture appeared to be greater in early, rather than late lactation, while the superior performance of OS HF fed TMR became more apparent as lactation progressed. It is evident that, compared to NZ HF, OS HF had difficulty consuming sufficient extra pasture to meet the extra maintenance costs associated with greater liveweight, and hence produced similar milksolids yields as NZ HF. Conversely, these results suggest that NZ HF were better adapted to pasture diets rather than TMR, especially in the second half of lactation.

The reasons for the lower intake by OS HF grazing pasture are speculative, but may be because they are not “good grazers”, because the intake limitations of fresh pasture become more evident with larger dairy cattle, or because they are lacking some metabolic adaptation that NZ HF have made.

In the first lactation of this study, the only genotype \times diet interaction observed was for liveweight gain during lactation (Kolver *et al.*, 2000). The greater number of genotype \times diet interactions identified in the third season suggests that with successive lactations, the unsuitability of OS HF for all-pasture systems, and to some extent NZ HF for intensive TMR systems, become more evident.

CONCLUSION

New Zealand HF performed better than OS HF when grazing pasture at a low stocking rate, but OS HF performed better than NZ HF when fed TMR. Differences appeared to be associated with a lower intake (% LW) by OS Grass compared to NZ Grass in early lactation, and to a higher intake (% LW) by OS TMR compared to NZ TMR during late lactation.

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