Journal of Agricultural Science, *Cambridge* (1999), **132**, 483–490. *Printed in the United Kingdom*

The effect of genetic merit and concentrate proportion in the diet on nutrient utilization by lactating dairy cows

C. P. FERRIS[1]*, F. J. GORDON[1,2,3], D. C. PATTERSON[1,2,3], M. G. PORTER[1] AND T. YAN[1]

[1] *Agricultural Research Institute of Northern Ireland*, *Hillsborough*, *Co. Down BT26 6DR*
[2] *The Queen's University of Belfast*, *Newforge Lane*, *Belfast BT9 5PX*
[3] *Agricultural and Environmental Science Division*, *Department of Agriculture for Northern Ireland*

(*Revised MS received 21 October 1998*)

SUMMARY

Sixty Holstein/Friesian dairy cows, 28 of high genetic merit and 32 of medium genetic merit, were used in a continuous design, 2 (cow genotypes) × 4 (concentrate proportion in diet) factorial experiment. High and medium merit animals had Predicted Transmitting Abilities for milk fat plus protein yield, calculated using 1995 as the base year (PTA_{95} fat plus protein), of 43·3 kg and 1·0 kg respectively. Concentrate proportions in the diet were 0·37, 0·48, 0·59 and 0·70 of total dry matter (DM), with the remainder of the diet being grass silage. During this milk production trial, 24 of these animals, 12 from each genetic merit, representing three animals from each concentrate treatment, were subject to ration digestibility, and nitrogen and energy utilization studies. In addition, the efficiency of energy utilization during the milk production trial was calculated.

There were no genotype × concentrate level interactions for any of the variables measured ($P >$ 0·05). Neither genetic merit nor concentrate proportion in the diet influenced the digestibility of either the DM or energy components of the ration ($P > 0{\cdot}05$). When expressed as a proportion of nitrogen intake, medium merit cows exhibited a higher urinary nitrogen output and a lower milk nitrogen output than the high merit cows. Methane energy output, when expressed as a proportion of gross energy intake, was higher for the medium than high merit cows ($P < 0{\cdot}05$), while urinary energy output tended to decrease with increasing proportion of concentrate in the diet ($P < 0{\cdot}05$). In the calorimetric studies, neither heat energy production, milk energy output and energy retained, when expressed as a proportion of metabolizable energy intake, nor the efficiency of lactation (k_l), were affected by either cow genotype or concentrate proportion in the diet ($P > 0{\cdot}05$). However when k_l was calculated using the production data from the milk production trial the high merit cows were found to have significantly higher k_l values than the medium merit cows (0·64 *v*. 0·59, $P < 0{\cdot}05$) while k_l tended to fall with increasing proportion of concentrate in the ration ($P < 0{\cdot}05$). However in view of the many assumptions which were used in these latter calculations, a cautious interpretation is required.

INTRODUCTION

The superior milk yield potential and correspondingly higher gross energetic efficiency for milk production of cows of high genetic merit, compared to those of medium genetic merit, have been well established (Veerkamp *et al*. 1994; Gordon *et al*. 1995*a*). The higher milk yields of high merit cows are to a large extent a reflection of their higher intakes, together with their ability to partition a greater proportion of the nutrients consumed into milk and less into tissue gain. However, it is still unclear if genotype has an effect on the partial energetic efficiency of lactation. This trial was undertaken to compare the efficiency with which nutrients are utilized by high and medium merit cows and to examine the effects of concentrate proportion in the diet on nutrient utilization. In addition, as this study was undertaken in conjunction with the trial described in a paper by Ferris *et al*. (1999), a further aim was to provide information to aid in the interpretation of the findings of the production trial.

* To whom correspondence should be addressed.

MATERIALS AND METHODS

The accompanying paper (Ferris *et al.* 1999) describes a 2×4 factorial design trial in which the milk production responses of dairy cows of two genotypes (high and medium genetic merit) were examined over a number of diets consisting of 0·37, 0·48, 0·59 and 0·70 concentrate, on a dry matter (DM) basis. High and medium merit animals had Predicted Transmitting Ability for fat plus protein, calculated using 1995 as the base year (PTA_{95} fat plus protein), of 43·3 (S.D. 9·59) kg and 1·0 (S.D. 10·67) kg respectively. During this production trial, 24 animals, 12 of high and 12 of medium genetic merit, representing three animals from each concentrate treatment within each genotype, were used in nutrient utilization studies. These studies commenced after a mean of 63 (S.D. 5·6) days on the production trial.

Animals were transferred two at a time from the main experimental group and tied in individual stalls within a cowshed, while continuing to be offered the treatment rations provided during the main production study. After 2 days in this environment, each animal was placed in an indirect open-circuit respiration calorimeter for 72 h. These chambers and their associated systems have been described by Gordon *et al.* (1995*b*). Measurements of gaseous exchange during the final 48 h period in the chambers were used in the calculation of heat production. Samples of milk produced during the final 48 h period were bulked and their gross energy and nitrogen concentrations determined. Samples of silage and concentrate offered during each of days 2 and 3 in the respiration chambers were analysed for oven dry matter, nitrogen and gross energy concentration, while silage samples were also analysed for toluene DM and volatile constituents. On completion of the 3 day period in the chambers, animals were returned to the individual standings in the cowshed where a 6-day ration digestibility and nitrogen balance study was undertaken using the procedures described by Mayne & Gordon (1984). Throughout the nutrient utilization studies, rations for each animal were prepared individually, with the silage and concentrate portions of the ration being mixed in a 'mini mixer'. Rations were offered *ad libitum* to allow a proportional refusal of 0·05. A sample of the refused ration was analysed daily for oven DM concentration. Daily intakes of silage and concentrates were calculated assuming no preferential selection of either silage or concentrate from the mixture offered. Analytical techniques employed on milk, feedstuffs, faeces and urine throughout the study were as described by Mayne & Gordon (1984).

All animals were returned to the experimental group on completion of the ration digestibility study. For welfare reasons, one medium merit animal on the 0·37 concentrate treatment was returned to the group without having completed the nutrient utilization study.

Energy utilization data were calculated using intake, milk output and heat production data recorded during the final 48-h period in the energy metabolism chambers. Faecal and urinary energy losses for the chamber period were calculated using the data from the digestibility study by assuming that they remained as a constant proportion of gross energy intakes. The metabolizable energy (ME) requirement for maintenance was calculated as outlined in Section 6·8.2 of the Agricultural and Food Research Council (AFRC 1990), while the ME available for production was determined as the difference between ME intake and ME required for maintenance. The efficiency of utilization of ME for lactation (k_l) was calculated, based on ME intake = ME maintenance + ME lactation + ME tissue change, using the methodology described in AFRC (1990). No feeding level correction was used as in the present study the cows were offered diets *ad libitum*. For cows in positive energy balance, k_l was calculated as milk energy output, plus tissue energy gain/0·95, as a proportion of ME available for production. This assumes that tissue deposition occurs with an efficiency of 0·95 k_l. For animals in negative energy balance, k_l was calculated as milk energy output minus $0{\cdot}84 \times$ tissue energy loss, as a proportion of ME available for production. The latter assumes that ME saved by tissue mobilization is equal to tissue energy loss divided by $k_l/0{\cdot}84$.

Statistical analysis

The results were analysed as a 2×4 factorial arrangement consisting of three replicates per treatment, with data for the animal which did not complete the study being replaced by missing plots.

RESULTS

For all of the variables examined in this trial, there were no significant ($P > 0{\cdot}05$) interactions between cow genetic merit and concentrate proportion in the diet and consequently only main effects have been presented. During the periods in the respiration chambers and during the ration digestibility study, high merit cows had significantly higher intakes and milk yields ($P \leqslant 0{\cdot}05$) than medium merit animals (Table 1). However, neither variable was significantly affected by concentrate proportion in the diet, although intakes did show a tendency to increase with increasing concentrate inclusion rates. There was some variation in milk yields and dry matter intakes (DMI) between the respiration chambers and digestibility study, and in general intakes tended to be higher during the digestibility study while milk yields tended to be higher in the respiration chambers. Ration DM digestibility was not significantly affected

Table 1. *Effects of cow genetic merit and concentrate proportion in the diet on daily DM intakes and milk yields during the nutrient utilization studies and on DM digestibility*

	Cow genetic merit		S.E.M.	Concentrate proportion in diet (DM basis)				S.E.M.
	High	Medium	(D.F. = 15)	0·37	0·48	0·59	0·70	(D.F. = 15)
Total DM intake (kg/day)								
Respiration chamber	20·4	17·9	0·61	18·5	19·9	18·0	20·4	0·86
Digestibility study	21·7	19·3	0·66	19·9	20·2	20·5	21·4	0·93
Milk output (kg/day)								
Respiration chamber	34·9	29·2	1·20	33·1	31·2	32·8	31·0	1·70
Digestibility study	33·6	27·7	1·28	30·5	28·6	33·2	30·5	1·81
Dry matter digestibility	0·799	0·790	0·0035	0·799	0·787	0·788	0·802	0·0049

Table 2. *Effect of cow genetic merit and concentrate proportion in the diet on nitrogen utilization in lactating dairy cows*

	Cow genetic merit		S.E.M.	Concentrate proportion in diet (DM basis)				S.E.M.
	High	Medium	(D. F. = 15)	0·37	0·48	0·59	0·70	(D. F. = 15)
Nitrogen inputs and outputs (g/day)								
Nitrogen intake	695	621	21·6	593	629	675	736	30·5
Nitrogen output in faeces	179	167	6	152	174	185	182	8·5
Nitrogen output in urine	284	278	9·6	258	265	277	323	13·5
Nitrogen output in milk	183	147	5·9	156	155	177	173	8·3
Nitrogen retention	48	30	6·4	28	35	36	58	9·1
Nitrogen digested	516	454	16·8	441	455	490	554	23·8
Utilization of nitrogen (proportional basis)								
Nitrogen digestibility	0·742	0·730	0·0053	0·743	0·723	0·725	0·752	0·0075
Urinary nitrogen/nitrogen intake	0·409	0·447	0·0078	0·434	0·425	0·411	0·441	0·0110
Urinary nitrogen/digested nitrogen	0·551	0·613	0·0109	0·585	0·589	0·568	0·586	0·0154
Milk nitrogen/nitrogen intake	0·264	0·239	0·0067	0·264	0·248	0·261	0·233	0·0095
Milk nitrogen/digested nitrogen	0·357	0·329	0·0103	0·357	0·343	0·360	0·310	0·0146

by either cow genetic merit or concentrate proportion in the diet ($P > 0·05$).

High merit cows had higher nitrogen intakes ($P < 0·05$), milk nitrogen outputs ($P < 0·001$) and nitrogen digested ($P < 0·05$) than animals of medium genetic merit (Table 2). Nitrogen intakes, urinary nitrogen outputs and nitrogen digested all increased with increasing proportion of concentrate in the diet ($P < 0·05$). Cow genotype had no effect on nitrogen digestibility ($P > 0·05$). Urinary nitrogen losses, when expressed as a proportion of either nitrogen consumed or nitrogen digested, were significantly higher in medium compared with high merit animals ($P \leqslant 0·01$), but were unaffected by concentrate proportion in the diet ($P > 0·05$). High merit animals on the other hand excreted a significantly higher proportion of nitrogen consumed in milk than did the medium merit animals ($P < 0·05$).

High merit cows had higher energy intakes and higher faecal, urinary and milk energy outputs ($P < 0·05$) compared to animals of medium genetic merit (Table 3). Both high and medium merit animals were in a similar state of negative energy balance during the period in the respiration chambers, while the degree of negative energy balance did not appear to be correlated to the proportion of concentrate included in the diet. The digestibility of the energy component of the diet was not affected by concentrate proportion in the ration ($P > 0·05$). Medium merit cows exhibited significantly higher methane energy

Table 3. *Effect of cow genetic merit and concentrate proportion in the diet on energy utilization in lactating dairy cows (data relates to final 48 hour period in the respiration chambers)*

	Cow genetic merit		S.E.M.	Concentrate proportion in diet (DM basis)				S.E.M.
	High	Medium	(D. F. = 15)	0·37	0·48	0·59	0·70	(D. F. = 15)
Energy inputs and outputs (MJ/day, unless stated otherwise)								
Total gross energy intake	373	332	11·8	341	367	332	370	16·6
Energy output in faeces*	79	71	2·3	71	80	72	76	3·2
Energy output in urine*	17	14	0·6	16	16	13	16	0·9
Energy output in milk	116	97	4·1	113	104	106	103	5·8
Energy output in methane	23	23	0·9	24	24	22	23	1·2
Heat production	148	139	3·8	140	146	140	148	5·3
Energy retention	−10	−11	6·7	−23	−3	−22	+6	9·4
Metabolizable energy intake	254	224	9·0	230	247	224	256	12·7
ME concentration (MJ/kg DM)	12·43	12·47	0·131	12·36	12·42	12·46	12·55	0·184
Animal liveweight	606	587	13·9	582	618	573	612	19·7
Utilization of gross energy (proportional basis)								
Energy digestibility	0·789	0·785	0·0043	0·789	0·781	0·782	0·797	0·0060
Methane energy/GE intake	0·063	0·070	0·0022	0·071	0·067	0·067	0·062	0·0032
Urine energy/GE intake	0·045	0·043	0·0010	0·048	0·044	0·041	0·042	0·0014
Milk energy/GE intake	0·313	0·295	0·0128	0·336	0·284	0·319	0·276	0·0182
ME/GE (q)	0·681	0·672	0·0054	0·670	0·671	0·674	0·692	0·0077
Utilization of ME								
Heat energy/MEI	0·587	0·627	0·0169	0·618	0·603	0·626	0·579	0·0239
Milk energy/MEI	0·460	0·441	0·0212	0·505	0·425	0·474	0·399	0·0300
Retained energy/MEI	−0·047	−0·067	0·0344	−0·123	−0·028	−0·101	0·022	0·0487
Respiratory quotient	1·05	1·07	0·007	1·05	1·06	1·05	1·07	0·010
k_l (AFRC, 1990)	0·55	0·52	0·012	0·54	0·53	0·52	0·55	0·017

* Faecal and urinary energy outputs (as a proportion of GEI) from digestibility study used to calculate faecal and urinary energy outputs in respiration chambers, by assuming similar proportional losses.

losses, as a proportion of gross energy intake, than the high merit cows ($P < 0·05$), while methane energy losses tended to decrease with increasing proportion of concentrate in the diet, although this effect was non-significant ($P > 0·05$). Urinary energy losses, as a proportion of gross energy intake, while not significantly affected by genetic merit ($P > 0·05$), decreased with increasing proportion of concentrate inclusion in the diet ($P < 0·05$). The calculated metabolizable energy concentration of the diet, although not significantly affected by treatment ($P > 0·05$), did tend to show a slight increase with increasing proportion of concentrate in the diet. Neither heat energy, milk energy nor retained energy, when expressed as a proportion of metabolizable energy intake, was affected by treatment ($P > 0·05$). In addition, neither cow genetic merit nor concentrate proportion in the diet had a significant effect on k_l ($P > 0·05$).

DISCUSSION

The nutrient utilization study described here had two main aims. Firstly, to provide information on the effects of cow genetic merit and concentrate proportion in the diet on the efficiency of nutrient utilization, and secondly, to provide information to help explain the findings of the dairy cow production study described by Ferris *et al.* (1999).

Effects of cow genetic merit on nutrient utilization

During both the digestibility and energy metabolism part of this study, high merit cows consumed greater quantities of DM and produced more milk than medium merit cows, in agreement with the findings of the study described by Ferris *et al.* (1999). That the digestibility of neither DM, nitrogen nor energy was significantly influenced by cow genetic merit confirms the findings of other workers (Grieve *et al.* 1976; Davey *et al.* 1983; Gordon *et al.* 1995*a*) that animals of high and medium genetic merit digest food with similar efficiency.

When expressed as a proportion of nitrogen digested, the lower urinary nitrogen excretion observed with the high merit cows relative to the medium merit cows, reflects the lower milk nitrogen output of the latter, together with the tendency of the high merit cows towards an increased nitrogen retention. This would suggest that nitrogen intakes with the medium merit animals were more than adequate to suffice their lactational and tissue requirements. Gordon *et al.* (1995*a*) found the opposite effect of cow genetic merit on urinary nitrogen excretion, however in their study high merit cows were in negative nitrogen balance, while medium and low merit animals were in positive nitrogen balance.

The higher methane energy output, when expressed as a proportion of GE intake, recorded with the medium merit animals relative to the high merit animals conflicts with the findings of Grainger *et al.* (1985) and Gordon *et al.* (1995*a*), who, using grass and grass silage based diets respectively, found that cow genetic merit had no effect on methane energy outputs. An increased rate of passage through the rumen could result in a reduced methane output (Van Es 1975); however, in this study, ration digestibility was unaffected by genetic merit suggesting that rate of passage through the rumen did not differ between genotypes. Grainger *et al.* (1985) and Gordon *et al.* (1995*a*) found urinary energy output to be unaffected by cow genetic merit, in line with the results of the current study. Despite the difference in methane energy outputs between genotypes the mean ME concentration of the diets were almost identical for both high and medium merit cows at 12·43 and 12·47 MJ/kg DM respectively.

It is however worth bearing in mind that data from the digestibility study were used to predict faecal and urinary outputs for the chamber period. However, as indicated in the results section (Table 1) intakes of animals varied between the digestibility study and the chambers, and as such the assumption of equal proportional outputs of faeces and urine between the two may not be completely valid.

Gross energetic efficiency for milk production did not differ significantly between the two genetic merits. Although Gordon *et al.* (1995*a*) found heat production, when expressed as a proportion of ME intake, to be significantly higher for high merit than for medium merit cows, no such effect was observed in this study and in fact the opposite trend occurred. However both Gordon *et al.* (1995*a*) and Belyea & Adams (1990) noted that heat production, when expressed on a per kg metabolic liveweight basis, decreased with decreasing genetic merit, in agreement with the values of 1·21 and 1·17 $MJ/kg^{0.75}$ observed in the present study for high and medium merit cows, respectively. The similar k_l values obtained for both high and medium merit cows in the current study, namely 0·55 and 0·52 respectively, would suggest that genetic merit has little effect on the partial efficiency of ME use for milk production. This is in line with the findings of Gordon *et al.* (1995*a*) who recorded k_l values of 0·58 for both high and medium merit cows, and supports the conclusions of Veerkamp & Emmans (1995) that there is no strong evidence to suggest a genetic difference in partial efficiencies. However k_l values in this trial were considerably below either the value of 0·62 (MAFF 1975) or the value of 0·66 which would be predicted on the basis of the metabolizability ($q = 0.68$) of the diets offered, using the equation of the ARC (1980). However, k_l values considerably lower than those predicted on the basis of metabolizability according to the ARC (1980) are common with grass silage based diets (Unsworth *et al.* 1994). This may reflect inaccuracies in the assumptions used to calculate maintenance requirements (Unsworth 1990). Yan *et al.* (1997) have suggested that the maintenance requirements of lactating dairy cows offered a silage based diet may in fact be 40% higher than those calculated using the equations of the AFRC (1990). When maintenance energy requirements in the current study were calculated as 0·67 $MJ/kg\ LWT^{0.75}$ (Yan *et al.* 1997), k_l values of 0·63 and 0·61 were obtained for the high and medium merit animals respectively, with these values being close to the value of 0·62 suggested by the MAFF (1975). Thus it is possible that the low k_l values frequently obtained in the past with grass silage based diets may have been a consequence of the energy requirement for maintenance being understated.

Effects of concentrate proportion in the diet on nutrient utilization

Although neither total DMI nor milk output were significantly affected by treatment, total DMI tended to increase with increasing proportion of concentrate in the diet, in line with the full set of intake data from the production study (Ferris *et al.* 1999). That no such effect was identifiable with milk yield in the present study reflects the small number of animals per treatment, and the fact that animals selected for the nutrient utilization studies were not balanced in terms of milk yield potential. Increasing concentrate proportion in the diet had no effect on the digestibility of the DM or energy component of the ration, reflecting the high quality of the silage offered. In addition it is possible that an increased rumen outflow rate, associated with the higher intakes achieved with increasing proportion of concentrate in the diet, may have depressed digestibility somewhat. Although the digestibility of the nitrogen component of the ration was significantly affected by treatment, there was no

Table 4. *Effect of cow genetic merit and concentrate proportion in the diet on energy utilization during the complete indoor production study**

	Cow genetic merit		S.E.M.	Concentrate proportion in diet (DM basis)				S.E.M.
	High	Medium	(D. F. = 51)	0·37	0·48	0·59	0·70	(D. F. = 51)
Gross energy intake (MJ/day)	401	378	5·8	359	384	405	408	7·9
Metabolizable energy intake (MJ/day)	268	252	3·9	232	253	273	280	7·7
ME required for maintenance (MJ/day)	58	58	0·7	57	59	58	59	1·4
Milk energy output (MJ/day)	121	102	2·6	105	108	117	114	5·1
Energy retention (MJ/day)	11·2	10·9	2·36	11·7	6·7	12·7	13·2	3·34
k_l	0·64	0·59	0·015	0·67	0·60	0·61	0·58	0·022

* Calculated as described in text.

obvious pattern in the data which could be related to concentrate proportion in the diet.

The non-significant decrease in methane losses with increased concentrate inclusion in the diet is in line with previous work and may be due to an increased rate of passage of digesta at higher intakes (Van Es 1975). That urinary energy output, when expressed as a proportion of gross energy intake, decreased with increasing proportion of concentrate in the diet, reflects the fact that actual urinary energy losses remained relatively constant irrespective of treatment. The linear increase in the ME concentration of the diets with increasing concentrate inclusion levels, from 12·36 MJ/kg DM at the 0·37 concentrate inclusion rate to 12·55 MJ/kg DM at the 0·70 concentrate inclusion rate reflects the patterns in urinary and methane energy losses. These values confirm the high quality of the silage offered and the fact that it had a similar ME concentration to that of the concentrate offered, namely 12·6 MJ/kg DM, as calculated from the ME concentrations for the individual ration ingredients. In view of the lack of treatment effects on proportional outputs of heat energy and milk energy, it is not unexpected that k_l was not significantly influenced by concentrate proportion in the diet. However Unsworth *et al.* (1994) recorded higher k_l values in experiments where concentrates were included in the diet, compared to those where silage was offered as the sole feed, while Offer *et al.* (1996) presented an equation which indicated an inverse relationship between k_l and forage:concentrate ratio.

One of the aims of this nutrient utilization study was to provide information to help explain the findings of the dairy cows production study described by Ferris *et al.* (1999). However a degree of caution is required in interpolating the results back to the main production trial, as intakes and milk yields recorded during the nutrient utilization study were lower than those recorded during the production study. While animals used in the nutrient utilization studies may not have been representative of all animals on the production trial, it is also possible that placing animals in the metabolism chambers, together with the use of a harness system to facilitate separation of faeces and urine, caused stress, and a consequent decline in intake and milk yield. The problems associated with these differing intakes and yields are highlighted in that during the energy metabolism study, irrespective of treatment, animals were in negative energy balance, while changes in body tissue reserves during the production study would suggest that animals were in either zero or positive energy balance. Consequently efficiencies recorded during the nutrient utilization studies may differ from those which occurred during the main production study. Nevertheless, the data presented in this paper suggest that differences in the efficiency of lactation between genotypes were small and are therefore unlikely to have been a major factor in the higher milk yields achieved with the high merit animals. In addition, concentrate proportion in the diet had little effect on k_l, and differences in milk yield associated with concentrate inclusions are unlikely to have been due to differences in efficiency of lactation.

Energy utilization during animal production study

To complete this examination of the effects of genetic merit and concentrate proportion in the diet on energy utilization, and to help overcome the difficulties involved in interpolating nutrient utilization data to the production study, the efficiency with which individual animals utilized energy during the production study (Ferris *et al.* 1999) were calculated (Table 4). Metabolizable energy intakes were calculated using the ME concentrations of the diets presented in Table 3, milk energy outputs using the equation of Tyrrell & Reid (1965) and maintenance energy requirements according to the AFRC (1990) using mean liveweight data for the period of the experiment. Energy balance during the trial was determined by linear regression of weekly liveweights (excluding data from week 1) against time, and by assuming each kilogram of liveweight loss or gain to have an energy concentration of 26 MJ/kg (AFRC 1990).

Using this approach, the calculated k_l values were 0·64 and 0·59 for the high and medium merit animals respectively ($P < 0{\cdot}05$), considerably higher than the values of 0·55 and 0·52 determined from the energy metabolism data when maintenance was calculated as described by AFRC (1990). It is suggested that part of the discrepancy may be due to animals in the respiration chamber being under stress with a consequent lowering of their efficiency of lactation. In addition, an over-estimation of energy retention during the production trial would also result in higher k_l values.

That errors may have arisen in the calculation of energy balance is supported in that the energy balance values calculated for the high and medium merit cows were similar, namely 11·2 and 10·9 MJ/day respectively. These values conflict with the condition score and scanning data which suggest that medium merit animals were in a greater state of positive energy balance than the high merit animals. In view of the many assumptions involved in these partial efficiency calculations, together with the possibility of a genetic bias to some of the associated errors, any definitive statement of a genetic basis to differences in partial efficiency would be unsound.

The decrease in k_l with increasing proportion of concentrate in the diet is contrary to the findings of Unsworth *et al.* (1994). However this trend is almost entirely driven by the 0·37 concentrate treatment, and as such a cautious interpretation is advised.

The authors thank the staff of the Energy Metabolism Unit for technical assistance and the staff of the Laboratory for undertaking chemical analysis.

REFERENCES

Agricultural and Food Research Council (AFRC) (1990). Technical committee on responses to nutrients. Report no. 5. Nutritive requirements of ruminant animals: energy. *Nutrition Abstracts and Reviews*, *Series B* **62**, 787–835.

Agricultural Research Council (ARC) (1980). *The Nutrient Requirements of Ruminant Livestock*. Slough: Commonwealth Agricultural Bureaux.

Belyea, R. L. & Adams, M. W. (1990). Energy and nitrogen utilization of high versus low producing dairy cows. *Journal of Dairy Science* **73**, 1023–1030.

Davey, A. W. F., Grainger, C., Mackenzie, D. D. S., Flux, D. S., Wilson, G. F., Brookes, I. M. & Holmes, C. W. (1983). Nutritional and physiological studies of differences between Friesian cows of high and low genetic merit. *Proceedings of the New Zealand Society of Animal Production* **43**, 181–187.

Ferris, C. P., Gordon, F. J., Patterson, D. C., Mayne, C. S. & Kilpatrick, D. J. (1999). The influence of dairy cow genetic merit on the direct and residual response to level of concentrate supplementation. *Journal of Agricultural Science*, *Cambridge* **132**, 467–481.

Gordon, F. J., Patterson, D. C., Yan, T., Porter, M. G., Mayne, C. S. & Unsworth, E. F. (1995*a*). The influence of genetic index for milk production on the response to complete diet feeding and the utilization of energy and nitrogen. *Animal Science* **61**, 199–210.

Gordon, F. J., Porter, M. G., Mayne, C. S., Unsworth, E. F. & Kilpatrick, D. J. (1995*b*). Effect of forage digestibility and type of concentrate on nutrient utilization by lactating dairy cattle. *Journal of Dairy Research* **62**, 15–27.

Grainger, G., Davey, A. W. F. & Holmes, C. W. (1985). Performance of Friesian cows with high and low breeding indexes. 2. Energy and nitrogen balance experiments with lactating and pregnant, non-lactating cows. *Animal Production* **40**, 389–400.

Grieve, D. G., Macleod, G. K., Batra, T. R., Burnside, E. D. & Stone, J. B. (1976). Relationship of food intake and ration digestibility to estimate transmitting ability, body weight, and efficiency in first lactation. *Journal of Dairy Science* **59**, 1312–1318.

Mayne, C. S. & Gordon, F. J. (1984). The effect of type of concentrate and level of concentrate feeding on milk production. *Animal Production* **39**, 65–76.

Ministry of Agriculture, Fisheries and Food (MAFF) (1975). *Energy Allowances and Feeding Systems for Ruminants*. *Technical Bulletin No*. 33. London: Her Majesty's Stationery Office.

Offer, N. W., Cottrill, B. R. & Thomas, C. (1996). The relationship between silage evaluation and animal response. In *Proceedings of the 11th International Silage Conference, Aberystwyth*, pp. 26–39.

Tyrrell, H. F. & Reid, J. T. (1965). Prediction of the energy value of cow's milk. *Journal of Dairy Science* **48**, 1215–1223.

Unsworth, E. F. (1990). The efficiency of utilization of metabolisable energy for lactation from grass silage-based diets. In *Proceedings of the 9th Silage Conference*, *Newcastle-upon-Tyne*, pp. 36–37.

Unsworth, E. F., Mayne, C. S., Cushnahan, A. & Gordon, F. J. (1994). The energy utilization of grass silage diets by lactating dairy cows. In *Proceedings of the 13th Symposium on Energy Metabolism of Farm Animals*, *Majacar*, *Spain*.

VAN ES, A. J. H. (1975). Feed evaluation for dairy cows. *Livestock Production Science* **2**, 95–107.

VEERKAMP, R. F. & EMMANS, G. C. (1995). Sources of genetic variation in energetic efficiency of dairy cows. *Livestock Production Science* **44**, 87–97.

VEERKAMP, R. F., SIMM, G. & OLDHAM, J. D. (1994). Effects of interaction between genotype and feeding system on milk production, feed intake, efficiency and body tissue mobilization in dairy cows. *Livestock Production Science* **39**, 229–241.

YAN, T., GORDON, F. J., AGNEW, R., PORTER, M. G. & PATTERSON, D. C. (1997). The metabolisable energy requirement for maintenance and the efficiency of utilization of metabolisable energy for lactation by dairy cows offered grass silage-based diets. *Livestock Production Science* **51**, 141–150.