A REVIEW OF THE EFFECTS OF DAIRY BREED ON FEED CONVERSION EFFICIENCY - AN OPPORTUNITY LOST?

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SUMMARY

The efficiency of conversion of feed to milk is an important determinant of farm productivity. One factor that has received little attention is the effect of breed on efficiency of feed use. Experimental data that has compared breeds (Holstein, Friesian, Jersey and Holstein-Friesian x Jersey crossbred cattle) for feed efficiency are reviewed. This includes data from New Zealand, USA and Europe. Feeds offered ranged from grazed pasture to total mixed rations. Experiments included short term component studies that measured feed intakes and milk production for periods ranging from 2 weeks to 7 months, whole lactation studies, farm systems comparisons over 3 years and calorimetry experiments. Differences between breeds in feed intake capacity, efficiency of milk solids production, energy metabolism and digestive capacity are highlighted. Opportunities for utilising breed differences in efficiency are outlined and future research is suggested.

Keywords: feed conversion efficiency, dairy cattle, Holstein, Jersey

INTRODUCTION

In a pasture-based dairy system, the amount of milk produced from a given amount of feed is a measure of the efficiency of the system. Breeding objectives seek to maximise net income per unit of feed consumed. Australian Breeding Values (ABVs) are calculated for production (fat, protein and milk) and non-production (e.g. cow survival, milking speed and temperament) traits and combined into an index known as the Australian Profit Ranking (APR).

Feed conversion efficiency (FCE) is an important component of the APR. It can be defined in many ways, but in this review, FCE is defined as the amount of milk solids (fat plus protein) produced per kg DM intake (g MS/kg DM). Improvements in FCE could be achieved, all other things being equal, if a cow:

1. Achieves a higher feed intake per unit liveweight (LW),
2. Has lower losses of energy in faeces, urine or methane, for a given intake,
3. Has a lower loss of energy as heat (mainly energy needed for maintenance), for a given intake, or
4. Partitions more metabolisable energy to milk and less to body tissue. This will improve FCE in the short term, but in the long term continued weight loss is not sustainable and so, unless points 1, 2 or 3 operate, there may be no long-term gain in FCE.

Although differences between cows differing in genetic merit have been observed for points 1 and 4 above, a review by Veerkamp and Emmans (1995) could find no large genetic differences between cows for points 2 and 3 above. However, in beef cattle, differences in maintenance occur, and are correlated with differences in productive potential of breeds (Frisch and Vercoe 1984).

Currently, ABVs are calculated within a breed and in the APR calculation, it is assumed that maintenance is directly correlated with LW, and losses of energy in faeces, urine and methane are similar for cows within a breed. There has been no major breed comparison study in Australia comparing FCEs for at least 20 years. Thus, there is a lack of Australian data to test the correlation of maintenance costs with LW and the losses of energy in faeces, urine and methane across different dairy breeds. At its annual conference in 2003, the United Dairyfarmers of Victoria requested a base change in ABVs so that all breeds could be compared equally for production and non-production traits. Given the lack of local research data, this review focuses on overseas data that compares FCEs of different breeds including Holstein, Friesian (New Zealand and British) and Jersey.

OVERSEAS RESEARCH DATA

Part and whole lactation studies

Experiments have varied in length from 14 to 300 days. There is a large variation in breeds studied and diets offered. In an attempt to reduce sources of variation between experiments, the data have been sorted by country in which the work was done. In the USA, the breeds studied were American Holstein and Jersey, and the diets were total mixed rations (TMR). In Europe, the breeds studied were Dutch Holstein-Friesian, Dutch Friesian, British Friesian, Danish Jersey and British Jersey, and the diets offered were TMR or roughage. In New Zealand (NZ), the breeds were NZ Friesian and Jersey, and the diets offered were pasture and pasture plus concentrates.

In every experiment, Jersey cows ate more DM per 100 kg LW than Holstein and Friesian cows, averaging 14.2% more (Table 1). When expressed as DM per kg metabolic LW ($LW^{0.75}$), Jersey cows ate 5.1% more than Holstein and Friesian cows. The differences in intake were smaller in NZ (7.6%) than in the USA (14.4%), and it is worth noting the large differences between these countries in the LW of the breeds. In the USA, the breeds are larger (Holstein 610 kg and Jersey 430 kg) than in NZ (Friesian 450 kg and Jersey 360 kg), resulting in a larger difference between the breeds in the USA (180 kg) compared with NZ (90 kg). Another difference is that the TMR diets in the USA were always offered *ad libitum* whereas in NZ, pasture diets were not. This would probably result in a smaller difference in intake between breeds.

Table 1. Effect of breeds (details in text) on intake and food conversion efficiency (FCE).

Reference	Intake (kg DM/100 kg LW)			FCE (g MS/kg DM)		
	H-F	J	% diff.[A]	H-F	J	% diff.[A]
USA						
Rastani *et al.* (2001)	3.34	3.59	-7.5	134	130	3.0
West *et al.* (1990)	3.17	3.74	-18	78	86	-10.3
Beaulieu and Palmquist (1995)	3.3	3.84	-16.4	108	108	0
Blake *et al.* (1986)	3.2	3.65	-14.1	1.4[B]	1.3[B]	7.1
Tyrrell *et al.* (1990)	4.08	4.73	-15.9	110	125	-13.6
EUROPE						
Oldenbroek (1988)	3.29[C]	4.05	-23.1	87.5	95.1	-8.7
	3.11[D]	3.84	-23.5	88.6	105.2	-18.7
Gibson (1986)	2.68	3.09	-15.3	42.3	43.1	-1.9
NZ						
L'Huillier *et al.* (1988)	2.9	3.2	-10.3	105	108	-2.9
Mackle *et al.* (1996)	2.55	2.66	-4.3	115	128.5	-11.7
Thomson *et al.* (2001)	2.8	3.03	-8.2	99	109.8	-10.9

[A] Difference calculated as (H-F – J)/H-F expressed as a %; [B] FCE is kg 4%FCM/kg DM; [C] TMR diet; [D] Roughage diet

The higher intake capacity of Jersey cows may be explained by their greater weight of gastrointestinal tract per kg LW compared with Holstein and Friesian cows. Smith and Baldwin (1974) observed that Holstein cows had only 0.88 or 0.95 of the digestive capacity (total weight of gastro-intestinal tract) of the Jersey cow expressed per LW or per $LW^{0.75}$, respectively. This observation was confirmed by Nagel and Piatkowski (1988; cited by Brade 1992), who reported that German Black-and-White (BW) cows had only 0.80 of the digestive capacity of Jersey cows when measured as rumen/reticulum volume per $LW^{0.75}$. The Jersey cows weighed 200 kg less than the BW cows, but their rumen/reticulum volume was only 20 L less than the BW cows. This suggests that Jersey cows have a large capacity to consume roughage per unit LW compared with the BW cows. Ingvartsen and Weisberg (1993) measured a 21% higher rate of passage in Danish Jersey compared to Friesian cows, and they commented that this would facilitate the Jersey's higher intake capacity.

A higher intake per kg LW should lead to higher MS per kg LW, if there is no change in losses from urine, faeces, methane and heat. In fact, the Jerseys had an average of 23% higher MS per LW (3.76 versus 3.06 g MS/kg LW for Holstein and Jersey, respectively; Table 1). The FCE values differ between experiments with generally lower values for cows gaining weight, with low milk yield, and when intake over the whole year is used instead of during lactation (Gibson 1986). The FCE was generally higher (8 out of 11 comparisons) for the Jersey compared with the Holstein and Friesian cows, averaging 6.2% higher (Table 1). Expressing FCE as MJ net milk energy per kg DM resulted in a similar difference in favour of the Jersey, averaging 6.4%. This is because, for a given MS, Jerseys produce more fat (which is energy dense), less protein and less lactose, and hence a similar energy. In a desktop study, Beever (2003) calculated that to produce a similar annual amount of fat plus protein (55.3 tonnes) with either 110 Jersey or 100 Holstein cows required the production of an extra 9 tonnes of lactose by the Holsteins. In addition, the Jersey herd required less feed for maintenance (lower overall LW), despite having 10 more cows (this equates to the Jersey having a higher yield per LW).

Oldenbroek (1988) observed that differences in FCE between Jersey and Holstein/Friesian (H/F) cows were greater on a roughage compared with a TMR diet. He suggested that differences in milk composition between the breeds could explain the difference in FCE. For optimal production, the Jersey cow needs more lipogenic precursors and less amino acids and glycogenic precursors than the H/F cows. Roughage diets yield more lipogenic precursors than TMR diets and could favour the Jersey cow.

Energy metabolism studies

Energy balances, measured using indirect open-circuit calorimetry, provide a detailed measure of partitioning of energy within the cow. Energy values are expressed per $LW^{0.75}$. Energy balances within breeds of NZ Friesian (Grainger *et al.* 1985) and NZ Jersey (Trigg and Parr 1981) cows showed that high genetic merit cows produced more milk and had a higher efficiency of milk production than cows of lower merit. Differences in losses of energy as faeces, urine, methane and heat were small and not significant. The higher milk production of the high merit cows reflected a higher intake and an ability to partition a greater proportion of nutrients consumed into milk and less into tissue gain.

Energy metabolism studies comparing different breeds are scarce. L'Huillier *et al.* (1988) compared NZ Friesian and Jersey cows offered pasture and measured a significantly lower heat production in Jersey cows. This was consistent with the report of Brody (1945) that American Jersey cows offered a TMR diet had a 7.9% lower metabolic rate (heat production measured as calories per $LW^{0.75}$) than Holstein cows. A more recent American study (Tyrrell *et al.* 1990) detected no differences in heat production between Holstein and Jersey cows offered a TMR diet. None of the 3 studies detected any consistent differences in losses of energy in faeces, urine or methane.

Farm systems comparisons

A recent farmlet study in NZ compared the performance of Friesians and Jerseys at 2 stocking rates. Results from the first year were reported by Ahlborn and Bryant (1992). Maximum net income based on 1990/91 costs and prices was at 3.0 and 3.7 cows/ha for Friesians and Jerseys, respectively. At these stocking rates, net income was 5% higher for Jerseys than for Friesians. Penno (1998) later reported data for the full 3 years. At the optimum stocking rates for MS production, Jersey cows produced 9.7% more (110 kg MS/ha) than Friesians, but this was comprised mainly of milk fat (100 kg). In contrast to the initial conclusion by Ahlborn and Bryant (1992), Penno (1998) concluded that when the stocking rate for optimum economic farm surplus (EFS) was calculated for each breed, the EFS was higher for the Friesians. This was because of the cost savings associated with requiring 1.2 less Friesian cows/ha outweighing the extra income of the Jerseys.

A desktop study (Lopez-Villalobos *et al.* 2000) examined the profitability of dairy herds under 3 mating systems involving Holstein-Friesian, Jersey and Ayrshire breeds. A deterministic model was developed to simulate the nutritional, biological and economic performance of dairy herds under NZ conditions. Under market values that existed at the time, crossbred herds were more profitable than the straight-bred herds, with the Holstein-Friesian x Jersey cross generating the highest profit.

DISCUSSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

This review has highlighted the paucity of research data on the effect of breeds on FCE. Despite this, it can be concluded that the Jersey cow has a larger digestive tract per unit LW than the Friesian or Holstein, and that this probably explains their greater intake capacity per unit LW. This enhanced intake capacity and ability to consume roughage could be an advantage for Jerseys in pasture-based systems because they are more forage-based and often with lower roughage quality than TMR diets.

There appear to be no differences between breeds in the losses of energy as faeces, urine and methane per $LW^{0.75}$. This agrees with work within breeds for cows that differed in genetic merit. Two out of 3 studies measured a smaller heat production for Jerseys, and the other study found no difference. If there is a difference in heat production between breeds, this could result in a difference in FCE because energy losses would be less and the energy spared could go to extra milk production. Holsteins may partition metabolisable energy more to milk and less to body tissue than do Jerseys, as indicated by the fact that a 14.2% advantage in intake to the Jersey only resulted in a 6% advantage in FCE. This could be explained by very low blood insulin levels of Holsteins, resulting in less blood glucose being stored in body tissue, and more being used for milk production (Fahey *et al*. 2003).

In summary, Jerseys appear to have a higher FCE measured as MS/DM, but the economic benefit from this is eroded because most of the extra MS is fat. Protein is twice as valuable as fat, plus there are costs in running the Jerseys at a higher stocking rate. If the 2 breeds are similar in profitability, the H-F x J crossbred is likely to be the most profitable due to improvements in FCE, health and fertility, partly due to heterosis. Therefore, there is an opportunity to use more Jersey semen for crossbreeding as is done in NZ. It is interesting that in the NZ dairy cow population, the Jersey has a 38% influence through purebred Jersey (15%) and crossbred H-F x J (23%). In Australia, the influence of the Jersey is much less at only 17% through Jersey (12%) and H-F x J (5%). We believe this is primarily due to the lack of objective information (health, fertility, longevity, FCE and profitability) for the different breeds under Australian conditions.

Based on this literature review, future research that could be undertaken to determine potential FCE differences between breeds (Holstein, Jersey and Holstein x Jersey) is:

- Measurements of heat production of cows,
- The FCE of cows measured over 365 days offered pasture-based diets in pens (to get accurate intakes). A difference of 6% in FCE could be detected using 80 cows of each of the 3 breeds,
- Estimation of LW using type classification so that intake can be estimated and used as an indicator of FCE, and
- Development of a test of FCE efficiency that can be carried out at an early age before first calving. This may involve a net feed efficiency test similar to that carried out in the beef industry or measurements of blood metabolites such as IGF-I.

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