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Conference Paper · June 2011

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Efficiency, cheese yield and carbon emissions of Holstein-Friesian, Jersey and crossbred cows: an overview

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ABSTRACT

This paper provides an overview on differences between Holstein-Friesian (HF), Jersey (J) and crossbred cows, for feed conversion efficiency (FCE), dry matter intake (DMI), cheese yield and carbon emissions. It was found that J cows have significantly higher DMI per kilogram of live weight (LWT) compared to HF and F1 HFxJ cows (3.64, 3.81 and 3.23 g DMI/kg LWT, respectively). A higher DMI per kilogram of LWT can result in more energy available for milk production, assuming that the maintenance requirements per unit of LWT are equal between the breeds. Estimates of FCE measured as grams of milksolids (milkfat plus milk protein) per kilogram of DMI were higher in J than HF cows (112 vs 97 g MS/kg DMI) in the reviewed papers. For grazing cows, a higher proportion of feed consumed is converted into milk production than used to cover maintenance energy requirements in J cows. This may result in lower greenhouse gas emission intensity from J than HF cows. Opportunities for the utilisation of breed differences to increase FCE and reduce carbon footprint and increase overall farm profitability in grazing dairy systems requires further farming system research to elucidate the relative efficiencies of the most common dairy breeds.

Keywords: Jersey; Holstein Friesian; feed conversion efficiency; carbon footprint, greenhouse gas.

INTRODUCTION

Feed conversion efficiency (FCE), the amount of milksolids (MS; fat plus protein) produced per unit of dry matter (DM) intake (DMI) (Kolver, 2007), is a useful measure of the productive performance of a farm feeding systems (Beever & Doyle, 2007). On the other hand, greenhouse gas (GHG) emissions from a farming system, described as the amount of carbon dioxide equivalents emitted per unit of animal product, is currently becoming an important aspect of consumer buyer decision. Feed conversion efficiency influences the amount of GHG emissions, and there is evidence (Mackle *et al.*, 1996; Aikman *et al.*, 2008; Prendiville *et al.*, 2010; Capper *et al.*, 2010; Xue *et al.*, 2011) showing differences in both FCE and GHG emissions between dairy cattle breeds. Holstein Friesian (HF) and Jersey (J) are the two most important dairy breeds in New Zealand, representing 42.8% and 13.8% of national herd, respectively, with their crossbred (HFxJ) making up 34.9% of the inventory (Livestock Improvement Corporation, 2010). This gives both breeds a large influence on the productive performance of the national herd and associated GHG emissions intensity. The objective of this study was to summarise literature on the differences between HF, J and HFxJ crossbred cows for DMI, MS production and FCE under both a grazing and an indoor total mixed ration feeding system, including a brief discussion on the carbon footprint and cheese yield.

Given limited New Zealand literature on this subject, overseas results are also included.

FEED INTAKE AND FEED CONVERSION EFFICIENCY

On a per head basis, J cows had lower total feed intakes than their HF and HFxJ counterparts. However, the opposite was observed when intake is expressed per unit of live weight (LWT) as an estimate of feed intake capacity (Table 1), J cows have a 12% greater average intake capacity than the HF cows (3.90 vs. 3.42 kg/100 kg LWT on a TMR diet and 3.22 vs. 2.91 kg/100 kg LWT on a pasture diet), this despite a 20.3% higher average total DMI by the HF than the J cows (19.0 vs. 14.7 kg DM/head). It was observed that the paper of Knowlton *et al.* (2010) reported a non-significant result despite an almost 10% difference between breeds. This may be due to small sample size as smaller differences have been found significant with larger sample sizes. At grazing, it has been reported (Aikman *et al.*, 2008; Prendiville *et al.*, 2010) that J cows had lower bite weight, higher bite rate, and shorter total grazing times per head, but longer grazing time per unit of DMI than HF cows. These behavioural differences resulted in greater pasture DMI/kg LWT for J compared to HF cows. Differences in DMI between J and HF appear to be larger with increasing difference in animal size between the breeds, such as HF and J cows from North America and Canada with an average LWT of 610 and 430 kg respectively, compared to 480 and 390 kg LWT for HF and J respectively in New Zealand (Grainger & Goddard 2007).

TABLE 1: Feed dry matter intake of Holstein-Friesian (HF), Jersey (J) and HFxJ crossbred cows for total mixed ration (TMR) and grazed pasture systems. NR = Not reported.

Breed			Difference (HF-J/HF) (%)	Significance	Feeding system	Type of feed	Country	Reference
HF	HFxJ	J						
Feed dry matter intake (kg dry matter/head)								
-	-	15.6	-	-	Indoor	TMR	England	Aikman *et.al.* (2006)
22.3	-	15.4	+30.9%	***	Indoor	TMR	England	Aikman *et al.* (2008)
22.7	22.1	-	-	-	Indoor	TMR	USA	Heins *et al.* (2008)
22.3	-	16.6	+25.5%	**	Indoor	TMR	USA	Knowlton *et al.* (2010)
21.4	20.1	17.0	+20.5%	NR	Indoor	TMR	USA	Olson *et al.* (2010)
10.5	-	8.5	+19.0%	***	Grazing	Pasture	New Zealand	Mackle *et al.* (1996)
16.9	16.2	14.7	+13.0%	***	Grazing	Pasture	Ireland	Prendiville *et al.* (2009)
16.9	16.2	14.7	+13.0%	***	Grazing	Pasture	Ireland	Prendiville *et al.* (2010)
Intake capacity (kg dry matter/100 kg live weight)								
3.29	-	4.05	-23.1%	*	Indoor	TMR	Netherlands	Oldenbroek (1988)
3.47	-	3.47	0%	NS	Indoor	TMR	England	Aikman *et al,* (2008)
3.55	-	3.90	-9.8%	NS	Indoor	TMR	USA	Knowlton *et al.* (2010)
3.71	3.99	4.19	-12.9%	NR	Indoor	TMR	USA	Olson *et al*. (2010)
3.11	-	3.84	-23.5%	NR	Indoor	Pasture	Netherlands	Oldenbroek (1988)
2.55	-	2.66	-4.3%	*	Grazing	Pasture	New Zealand	Mackle *et al.* (1996)
2.80	-	3.03	-8.2%	**	Grazing	Pasture	New Zealand	Thomson *et al.* (2001)
3.39	3.63	3.99	-17.9%	**	Grazing	Pasture	Ireland	Prendiville *et al,* (2010)

The observed differences in feed intake capacity at grazing between the breeds implies that HF cows have lower FCE than their J counterparts, as a greater proportion of their metabolisable energy intake will be allocated to maintenance requirements leaving less for milk production (Grainger & Goddard 2007). This greater dilution of maintenance requirements in J cows will lead to: higher MS production per kilogram of DMI (FCE), and MS per unit of LWT for the J cows. Dilution of maintenance energy requirements is important under grazing conditions, where the amount and quality of feed most often restricts milk yield (Kolver & Muller, 1998). However, under intensive indoor feeding systems, with high quantity and quality of feed offered, the greater maintenance requirements of HF cows is compensated for by their high milk yield (Capper *et al.,* 2009).

Individual FCE is a trait that is difficult to measure in grazing cattle because the DMI of individual animals cannot be measured; therefore, estimates are used, with varying levels of accuracy (Reeves *et al*, 1996). Under grazing conditions in New Zealand dairy systems, a proxy for FCE has been devised through the inclusions of some predictor traits in the breeding worth (BW) index. The BW index expresses farm profit per four and a half tonne of feed consumed and accounts for the animal's breeding values for live weight, milk fat, milk protein, litres of milk, somatic cell score, residual survival and fertility, with each weighted by respective economic values (Harris *et al.*, 1996). The LWT and yields of milk, fat and protein affect FCE.

Table 2 supports that production efficiency of J cows is higher than those of HF per unit of both DMI and LWT. It follows that compared to HF cows, the higher intakes per kilogram LWT (Table 1) and the lower amount of feed diverted into maintenance in J cows results in higher MS production per kilogram of LWT, or a higher FCE. In turn, while the total feed DMI are lower for the J than HF cows, J cows were able to produce more MS per unit of DMI (112 vs. 97 g MS/kg DMI for J and HF cows respectively) (Figure 1). This trend was in agreement with Grainger and Goddard (2007) who reviewed the relative efficiencies of dairy breeds. Feed passage through the gastrointestinal tract has been shown to be faster in J than with HF cows (Aikman *et al.,* 2008) which is associated with higher particle breakdown. This difference in the rate of passage of feed was associated with increased feeding and rumination time per kilogram of DM consumed for J cows than for HF (Aikman *et al.,* 2008). The above suggests that temporal constraints to achieve optimum eating and rumination times at grazing are greater on HF than on J cows due to a greater volume of feed to process in HF cows, differences in feeding behaviour and differences in the rate of passage of feed (Aikman *et al.,* 2008; Prendiville *et al.,* 2010). Finally, the greater capacity of the J to utilize

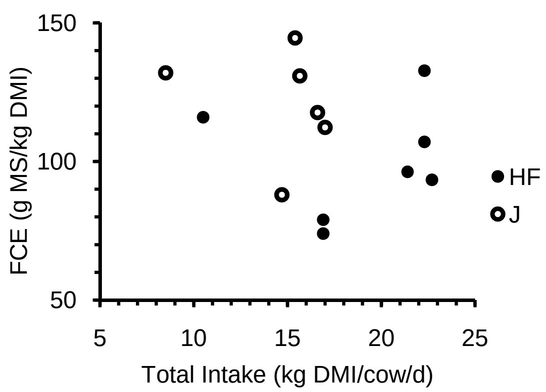
TABLE 2: Daily milksolids production per unit of live weight and per unit of dry matter intake for Holstein-Friesian (HF), Jersey (J) and HFxJ crossbred cows for total mixed ration (TMR) and grazed pasture systems. NR = Not reported.

Breed			Difference (HF-J/HF) (%)	Significance	Feeding system	Type of feed	Country	Reference
HF	HFxJ	J						
Daily milksolid production (g MS/100 kg live weight)								
460	-	502	-9.1%	***	Indoor	TMR	England	Aikman *et.al.* (2008)
420	440	-	-	-	Indoor	TMR	USA	Heins *et al.* (2008)
380	-	436	-14.7%	**	Indoor	TMR	USA	Knowlton *et al.* (2010)
350	410-	470	-34.2%	NR	Indoor	TMR	USA	Olson *et al.* (2010)
280	-	330	-17.8%	NR	Grazing	Pasture	New Zealand	Mackle *et al.* (1996)
270	320	350	-29.6%	***	Grazing	Pasture	Ireland	Prendiville *et al.* (2009)
250	300	330	-32.0%	***	Grazing	Pasture	Ireland	Prendiville *et al.* (2010)
Daily milksolid production (g MS/kg dry matter intake)								
87.5	-	95.1	-8.6%	NR	Indoor	TMR	Netherlands	Oldenbroek (1988)
-	-	130.9	-	-	Indoor	TMR	England	Aikman *et al,* (2006)
132.8	-	144.6	-8.9%	***	Indoor	TMR	England	Aikman *et al,* (2008)
93.4	92.9	-	-	-	Indoor	TMR	USA	Heins *et al.* (2008)
107.1	-	117.7	-9.9%	**	Indoor	TMR	USA	Knowlton *et al.* (2010)
96.3	103.3	112.3	-16.6%	NR	Indoor	TMR	USA	Olson *et al.* (2010)
88.6	-	105.2	-18.7%	NR	Indoor	Pasture	New Zealand	Oldenbroek (1988)
116	-	132	-13.8%	**	Grazing	Pasture	New Zealand	Mackle *et al.* (1996)
79	87	88	-11.4%	***	Grazing	Pasture	Ireland	Prendiville *et al,* (2009)
74	82	81	-9.5%	**	Grazing	Pasture	Ireland	Prendiville *et al,* (2010)

dietary fibre may be of increased importance to be exploited where cows are fed pasture (Aikman *et al.,* 2008; Prendiville *et al.,* 2010).

The dilution of maintenance energy requirements resulting in higher FCE per cow in J than HF cows suggests lower GHG emission intensity maybe associated with farming J cows (Capper *et al.*, 2010) with restricted feeding systems such as grazing, where the HF cow does not reach their maximum intake capacity due to the temporal constraints of grazing. However, if feed intake could be maximised the dilution of maintenance would be expected to be equal for both breeds. For a farming system to achieve a certain production level, larger numbers of J cows will be required, thus increasing maintenance costs per hectare but potentially decreasing total maintenance requirements to produce the same amount of milk product. This was an 8% decrease in maintenance energy requirements in the trial of Capper *et al.* (2010) and a 5.5% decrease in the trial of Lopez-Villalobos *et al.* (2000). As an example, for a farm situation with 12,000 kg DM produced per hectare, without supplementary feeding, 2.86 J cows and 2.41 HF cows would be required per hectare to achieve the same level of feed demand (kg LWT/t DMI) (Lopez-Villalobos *et al.*, 2000). This results in a maintenance feed demand of 4,676 vs 4,499 kg DM/ha for J and HF cows, respectively, and FCE of

FIGURE 1: Association between feed conversion efficiency (FCE) and total feed intake of dry matter reported by Mackle *et al.* (1996); Aikman *et al.* (2006); Aikman *et al.* (2008); Heins *et al.* (2008); Prendiville *et al.* (2009); Knowlton *et al.* (2010); Prendiville *et al.* (2010) and Olson *et al.* (2010).



155 vs 147 g MS/kg DM for J and HF cows, respectively. Thus despite the similar maintenance cost per hectare, the J cows still showed a higher FCE/ha.

True profitability from exploiting the greater FCE of J cows would depend on the payment system applied. The current payment ratio of fat to protein in New Zealand is \$3.24 vs. \$9.81/kg for fat

TABLE 3: Yield of cheese (kg cheese/100L of milk) produced from milk of Holstein Friesian and Jersey cows.

Type of milk	Type of cheese	Cow breed		Difference (HF-J/J) (%)	Reference
		Holstein Friesian	Jersey		
Raw milk	Cheddar	9.8	12.3	-20.3%	Campbell (1966)
Standardised milk	Cheddar	11.4	13.0	-12.3%	Wiles (1988)
Standardised milk	Cheddar	10.8	12.0	-10.0%	Auldist *et al.* (2004)
Standardised milk	Pategras	9.8	11.2	-12.5%	Chávez *et al.* (2002)

and protein respectively. This has not been of sufficient advantage to warrant changing to J farming as the increase in FCE is associated with an increase in fat production which has a lower economic value than protein.

YIELD AND QUALITY OF DAIRY PRODUCTS

In cheese making trials (Auldist *et al.*, 2004) and desktop simulations (Campbell, 1966; Wiles, 1988; Chávez *et al.*, 2002), J milk was shown to have higher yields of cheese per unit of standardised milk (13.7 g solids/kg milk), with faster curd formation rates (Auldist *et.al*., 2004) than HF milk. This comes from the higher concentrations of both fat and protein in the milk of J cows (Blake *et al.*, 1980). However, it must be noticed that when the milk is standardised to a constant milksolids content the differences between breeds disappears (Auldist *et al.,* 2004).

The milk of J cows has a very high fat concentration, which requires this milk to have fat removed to standardise the milk for cheese production. However, this does allow for extra fat to be used for production of butter. It is shown in Table 3 that J cows still produces more cheese than HF cows after standardisation to a constant protein to fat ratio, which may be attributed to a higher total MS, a higher casein number (g casein/g total protein) (Blake *et al.*, 1980) and better cheese-making characteristics of the J milk compared to the HF milk (Kielczewska *et al*., 2008).

CARBON FOOTPRINT

Carbon footprint can be expressed as emissions of carbon dioxide equivalents per kilogram of cheese produced (Münger & Kreuzer, 2008; Capper *et al.,* 2010). Consumers are becoming increasingly aware of this environmental impact of dairy farming.

Capper *et al.* (2010) reported that under the American TMR feeding system, the carbon footprint of J cheese is 18% lower than that of HF cheese despite an increase in the number of cows needed to produce the same volume of milk. The total maintenance energy required to produce this milk is 8% less; a figure which is comparable with Lopez-Villalobos *et al.* (2000) where the J cows required 5.5% less maintenance feed than the HF cows. This difference was attributed to decreases in maintenance energy requirements (21%), water use (27%) and cropping area (23%) per kg of cheese for J compared to HF cows, but may increase per animal fixed costs. There is also a reduction in fossil fuel use, methane production and nitrous oxide production in the J breed compared to the HF breed. The higher digestion rate and higher apparent NDF digestibility of the J partially explains the higher FCE and lower GHG emission levels of the J compared to HF cows (Aikman *et al.,* 2008; Prendiville *et al.,* 2009).

CONCLUSIONS

From the reviewed papers, J cows have 12% higher DMI per unit of LWT and 23% higher MS production per unit of LWT than HF cows. Consequently, J cows have been shown to have 12% higher FCE (g MS/kg DMI) than their HF counterparts. This higher intake per unit of LWT probably leads to higher pasture utilisation in grazing situations for J compared to HF cows. With higher digestion of fibre, the J cow may also be able to better utilise the energy in the feed in grazing dairy systems, thus increasing the FCE.

In the studies reviewed, it was found that J cows showed an average FCE of 112 g MS/kg DMI compared to 97 g MS/kg DMI in HF cows, whereas HFxJ cows seem to have a higher FCE than the parental average. Research, particularly under grazing systems, is required to show such an advantage for J cows.

REFERENCES

Aikman, P.C.; Beever, D.E.; Humphries, D.J. 2006: The effect of incremental replacement of wheat with soya hulls in diets of Jersey cows on lactational performance, diet digestibility and feeding behaviour. *Livestock Science* **104**: 23-32.

Aikman, P.C.; Reynolds, C.K.; Beever, D.E. 2008: Diet digestibility, rate of passage, and eating and rumination behaviour of Jersey and Holstein cows. *Journal of Dairy Science* **91**:1103-1114.

Auldist, M.J.; Johnston, K.A.; White, N.J.; Fitzsimons, W.P.; Boland, M.J. 2004: A comparison of the composition, coagulation characteristics and cheesemaking capacity of milk from Friesian and Jersey dairy cows. *Journal of Dairy Research* **71**: 51-57.

Beever, D.E.; Doyle, P.T.; 2007: Feed conversion efficiency as a key determinant of dairy herd performance: a review. *Australian Journal of Experimental Agriculture* **47**: 645-657.

Bitman, J.; Wood, D.L.; Miller, R.H.; Tyrrell, H.F.; Reynolds, C.K.; Baxter, H.D. 1996: Comparison of milk and blood lipids in Jersey and Holstein cows fed total mixed rations with or without whole cottonseed. *Journal of Dairy Science* **79**: 1596-1602.

Blake, R.W.; Nmai, I.B.; Richter, R.L. 1980: Relationships between distribution of major milk proteins and milk yield. *Journal of Dairy Science* **63:** 141-147.

Campbell, I.L. 1966: Are we using the right breed? *Dairy Farming Annual,* Massey University, Palmerston North, New Zealand. p. 9-18.

Capper, J.L.; Castañedna-Gutiérrez, E.; Cady, R.A; Bauman, D.E. 2008: The environmental impact of bovine somatotropin (rbST) use in dairy cattle. *Proceedings of the National Academy of Sciences* **105**: 9668-9673.

Capper, J.L.; Cady, R.A.; Bauman, D.E. 2009: The environmental impact of dairy production: 1944 compared with 2007. *Journal of Dairy Science* **87**: 2160-2167.

Capper, J.L.; Cady, R.A. 2010: A point-in-time comparison of the environmental impact of Jersey vs. Holstein milk production. *Journal of Dairy Science* 93: E-Suppl. 1.

Chávez, M.S.; Comerón, E.A.; Romero, L.A.; Taverna, M.A.; Aronna, M.S. 2002: Respuesta productiva de vacas de raza Jersey y Holando sometidos a dos sistemas de alimentación. 3- Aptitud tecnológica de la leche producida por vacas Holando Agentino y Jersey. Revista Argentina de Producción Animal 22(Supplement 1): 398-399. [Proceedings of the Argentinean Animal Production Society]

Grainger, C.; Goddard, M.E. 2007: A review of the effects of dairy breed on feed conversion efficiency- an opportunity lost? *Animal Production in Australia* **25**: 77-80.

Harris, B.L.; Clark, J.M.; Jackson, R.G. 1996: Across breed evaluation of dairy cattle. *Proceedings of the New Zealand Society of Animal Production* **56**: 12-15.

Heins, B.J.; Hansen, L.B.; Seykora, A.J.; Hazel, A.R.; Johnson, D.G.; Linn, J.G. 2008: Crossbreds of Jersey x Holstein compared to pure Holsteins for body weight, body condition score, dry matter intake, and feed conversion efficiency during the first one hundred and fifty days of first lactation. *Journal of Dairy Science* **91**: 3716-3722.

Kielczewska, K.; Czerniewicz, M.; Kruk, A. 2008: A comparative analysis of the technological usability of milk of Jersey and Holstein-Friesian cows. *Polish Journal of Natural Sciences* **23:** 91-98.

Knowlton, K.F.; Wilkerson, V.A.; Casper, D.P.; Mertens, D.R 2010: Manure nutrient excretion by Jersey and Holstein cows. *Journal of Dairy Science* **93**: 407-412.

Kolver, E.S.; Muller, L.D. 1998: Performance and nutrient intake of high producing Holstein cows consuming pasture or a total mixed ration. *Journal of Dairy Science* **81**: 1403-1411.

Kolver, E.S. 2007: Definitions and concepts of feed conversion efficiency and prospects for manipulation. *Proceedings 3rd Dairy Science Symposium, National Dairy Alliance,* Chapman, D,F.; Clark, D.A.; Macmillan, K.L.; Nation, D.P. eds. National Dairy Alliance, Melbourne, Victoria, Australia. p. 36-64.

Livestock Improvement Corporation. 2010; Dairy Statistics 2009-10. Livestock Improvement Corporation, Hamilton, New Zealand. 52 pp.

Lopez-Villalobos, N.; Garrick, D.J.; Holmes, C.W.; Blair, H.T.; Spelman, R.J. 2000: Profitabilities of some mating systems for dairy herds in New Zealand. *Journal of Dairy Science*. **83**:144-153.

Mackle, T.R.; Parr, C.R.; Stakelum, G.K.; Bryant, A.M.; MacMillian, K.L. 1996: Feed conversion efficiency, daily pasture intake, and milk production of primiparous Friesian and Jersey cows calved at two different liveweights. *New Zealand Journal of Agricultural Research* **39**: 357-370.

Münger, A.; Kreuzer, M. 2008: Absence of persistent methane emission differences in three breeds of dairy cows. *Australian Journal of Experimental Agriculture* **48**: 77-82.

Oldenbroek, J.K. 1988: The performance of Jersey cows and cows of larger dairy breeds on two complete diets with different roughage contents. *Livestock Production Science* **18**: 1-17.

Olson, K.M.; Cassell, B.G.; Hanigan, M.D. 2010: Energy balance in first-lactation Holstein, Jersey, and reciprocal F1 crossbred cows in a planned crossbreeding experiment. *Journal of Dairy Science* **93**: 4374-4385.

Prendiville, R.; Pierce, K.M.; Buckley, F. 2009: An evaluation of production efficiencies among lactating Holstein-Friesian, Jersey and Jersey x Holstein-Friesian cows at pasture. *Journal of Dairy Science* **92**: 6176-6185.

Prendiville, R; Lewis, E.; Pierce, K.M.; Buckley, F. 2010: Comparative grazing behaviour of lactating Holstein-Friesian, Jersey and Jersey x Holstein-Friesian dairy cows and its association with intake capacity and production efficiency. *Journal of Dairy Science* **93**: 764-774.

Reeves, M.; Fulkerson, W.J.; Kellaway, R.C.; Dove, H., 1996: A comparison of three techniques to determine the herbage intake of dairy cows grazing kikuyu (*Pennisetum clandestinum*) pasture. *Australian Journal of Experimental Agriculture* **36**: 23-30.

Thomson, N.A.; Kay, J.K.; Bryant, M.O. 2001: Effect of stage of lactation on the efficiency of Jersey and Friesian cows at converting pasture to milk production or liveweight gain. *Proceedings of the New Zealand Society of Animal Production* **61**: 213- 216.

Wiles, P.G. 1988. Cost model comparing differences in returns for milk produced by Friesian and Jersey type herds. II. Milk manufactured into cheese. *New Zealand Journal of Dairy Science and Technology* **23**: 223-237.

Xue, B; Yan, T; Ferris, C.F.; Mayne, C.S. 2011: Milk Production and energy efficiency of Holstein and Jersey-Holstein crossbred dairy cows offered diets containing grass silage. *Journal of Dairy Science* **94**: 1455-1464.