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Are high breeding worth index cows more feed conversion efficient and nitrogen use efficient?

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ABSTRACT

Future dairy farming in New Zealand will require increases in milksolids production and reduced impact on the environment. Cows which are more feed conversion efficient (FCE) and nitrogen use efficient (NUE) will help achieve these targets. In March 2010, eight High breeding worth (BW = 198), High production worth (PW = 319) and eight Low BW (57) PW (10) cows were housed in metabolism stalls and fed low quality perennial ryegrass-based herbage (metabolisable energy = 9.87 MJ/kg DM; crude protein = 15.2 g/100g DM). High BW cows had higher dry matter intakes (DMI) (16.0 vs 14.8 kg DM/cow/d, P <0.05) and produced more milksolids (1.32 vs 1.03 kg MS/cow/d, P <0.001). Due to their higher DMI, the High BW cows also had a higher feed N intake than the Low BW cows (388 vs 360 g N/cow/d, P <0.05), and partitioned more of their intake N to milk (22.0 vs 18.5 %, P <0.01) and less to urine (39.7 vs 46.2%, P <0.01). Overall, the High BW cows were more FCE (82.7 vs 70.2 g MS/kg DMI, P <0.01) and more NUE (22.0 vs 18.5 %, P <0.01) when fed low quality herbage in late lactation.

Keywords: breeding worth; dairying; milksolids yield; nitrogen use efficiency; production worth.

INTRODUCTION

The predominant component of the New Zealand dairy cow's diet is perennial ryegrass (*Lolium perenne*) which provides a grazable herbage base for highly profitable farm systems throughout the country. However, ryegrass nutrient composition is variable, dependent on season and climate and is rarely optimal for cow requirements, in contrast to total mixed rations (TMR). The nitrogen (N) content of ryegrass often exceeds cow requirements (Jarvis *et al.*, 1989) and the digestible energy content can limit the ability of rumen microbes to make full use of the available N. In contrast, low N concentration in herbage can limit milk production in late summer and autumn. Variations in herbage quality mean only 20 to 30% of dietary N is utilised for milk protein synthesis (Tamminga, 1992; Castillo *et al.*, 2000; Waghorn *et al.*, 2007) both in spring when pasture N concentration and milk production are high, and in late summer/autumn when feed quality and available energy for milk production are low. However, the quantity of N excreted, especially in urine, is highest in spring, because high N concentrations in herbage are associated with high intakes.

If a higher proportion of feed N were captured in milk (nitrogen use efficiency: NUE), and less deposited as urine, N losses through leaching of nitrates (NO_3^-) into ground water, and volatilisation and denitrification of ammonia (NH_3) and nitrous oxide (N_2O) would be reduced (de Klein *et al.*, 2008; Pacheco & Waghorn, 2008). High producing or efficient cows offer an opportunity to reduce losses by either a reduction in the proportion of energy, and N, associated with maintenance, or more efficient utilisation of feed. This paper reports

the first of several experiments comparing NUE in dairy cows with either high breeding worth (BW) and high production worth (PW) or cows with low BW and low PW.

BW ranks a cow on expected genetic ability to breed profitable and efficient replacements, and relates mainly to her offspring. The BW ranking is derived from breeding values (BV's) which are based on ancestry, her own lactation performance and progeny information for seven traits (protein, milkfat, milk yield, somatic cell, live weight, fertility and residual survival) combined with specific economic values. The economic values are calculated from current farm economic models taking into account milk production and expected payouts, income from cull cows and bobby calf sales, costs in generating and rearing replacements and dairy cash expenses, all scaled to a reference unit of feed for an average cow (4,500 kg DM/year). Thus a BW of 80 indicates a cow is expected to generate an extra \$40 profit per year, per unit of feed, through breeding daughters whose genetics come from the bull and cow, which are more efficient producers than the daughters of a cow with BW of 0.

PW is mostly about the cow herself and her own ability to be a profitable and efficient lifetime producer. PW is calculated similarly to BW but using a cow's production values (PV) for only four traits (protein, milkfat, milk yield and live weight). Thus a PW of 58 indicates a cow is expected to generate an extra \$58 profit per year than a cow with a PW of 0.

The different characteristics of cows with divergent BW/PW rankings include milk protein

synthesis, so a difference in NUE between groups was anticipated. This experiment was undertaken to measure those differences when herbage was poor quality.

MATERIAL AND METHODS

Experimental design and management

A 9-day indoor experiment was conducted in March 2010 at DairyNZ's Lye Farm, Hamilton, New Zealand using 16 multiparous dairy cows in late lactation (221 ± 22 days in milk (DIM)). Cows were purposely selected with either a High or Low BW/PW (Table 1). Both groups included cows from six different bulls and while the High BW/PW cows were all Friesian-Jersey crossbreds (F12J4), the Low BW/PW cows were all Friesian except for two crossbreds (one F12J4 and one F8J8). Cows were fed in individual metabolism stalls that allowed faeces and urine to be collected. The first four days allowed cows to adapt to the housing and feeding. Measurements were made over the final five days.

Feed and intake measurements

Cows were fed freshly cut perennial ryegrass-based herbage at 08:40 h and 16:00 h daily to ensure daily refusals were approximately 10% of feed offered (*ad libitum*). Dry matter intake (DMI) was measured twice daily, weighing herbage offered and refused and adjusting for DM content. Herbage samples of approximately 100 g DM, were collected daily, oven-dried at 65°C, the chemical composition analysed by near infrared spectrophotometry (NIRS systems 6500; FeedTECH, Palmerston North, New Zealand) and metabolisable energy (ME) content predicted. The principal focus was on the calculation of N concentration (%) in the diet, estimated as crude protein CP (%) $\div 6.25$, and the total N intake (g/d) of each cow.

Milk measurements

Milk yield (kg/cow/d) was measured daily in the afternoon at 15:30 h plus the following morning at 07:30 h, with samples taken to determine milkfat (%), milk protein (%) and milk urea nitrogen (MUN) content (mmol/L) by infrared spectrophotometry (SCC; Fossomatic™, Foss Electric, Hillerod, Denmark). Milk solids yield (fat + protein; kg MS/cow/d) and N concentration, calculated as milk protein (%) $\div 6.38$, of individual milk samples were then calculated. Feed conversion efficiency (FCE) was calculated and expressed as g MS/kg DMI.

Faeces and urine measurements

Total faeces and urine output (kg/cow/d) were collected daily into separate containers, with the urine containers sealed to minimise N volatilisation losses. Faecal samples were freeze dried before measurement of N concentration using the Dumas

combustion method (AOAC 990.03, 2006). Daily urine samples were acidified (to pH <4) using hydrochloric acid to prevent N volatilisation before storage at -20°C and measurement of total N concentration. Total N outputs (g/d) in milk, faeces and urine, and retained N (N intake minus total N output) were calculated daily for each cow. The distribution of N between milk, faeces and urine is expressed as a percentage of the total N intake.

Statistical analyses

Data from the five measurement days were averaged for individual cows for each variable and these means were analysed using analysis of variance (ANOVA, GenStat 13, VSN International, 2010) including High and Low BW/PW as a treatment factor. The tabulated data show the treatment means, standard error of difference and P values.

RESULTS AND DISCUSSION

Feed characteristics

Herbage fed during the experiment had a DM content of 21.0 % and CP was 15.2 g/100g DM with a predicted ME of 9.87 MJ/kg DM. Other chemical components of the feed (g/100g DM) included neutral detergent fibre, 58.9, acid detergent fibre, 31.8, lipid, 3.46, soluble sugars and starch, 6.01, and ash, 9.76, and predicted organic matter digestibility was 65.7%. The calculated N concentration of the feed was 2.43%. This is a typical value for herbage fed to cows on dairy farms in the same Waikato region during late lactation (S.L. Woodward, Unpublished data). Diet and cow data were entered into the Cornell Net Carbohydrate and Protein System (CNCPS v6.1.39) model (Fox *et al.*, 1992; Russell *et al.*, 1992; Sniffen *et al.*, 1992). The model predicted cow (High and Low BW/PW) performance, based on feed composition, digestion and nutrient supply, would be limited by the low ME content in the diet, rather than the CP content.

DMI and milk production

The High BW/PW cows had higher DMI and milk yields than the Low BW/PW cows (Table 1). Differences between the two groups of cows in milk composition (Table 1), namely higher milkfat concentration and higher milk protein concentration may have been associated with the higher level of Jersey genetics in the High BW/PW group and resulted in MS production being 28% higher (Table 1) from the High BW/PW cows than those with Low BW/PW. This higher MS production also meant the High BW/PW cows had a significantly higher FCE (Table 1). In contrast, calorimetric research in the early 1980s indicated that the difference in milk solids production between Jersey cows with high or low breeding index was not a result of differences in efficiency of energy

TABLE 1: Mean breeding worth (BW), production worth (PW) and live weight of the eight High BW/PW cows and the eight Low BW/PW cows prior to the start of the nine day individual metabolism experiment. Measurements of intake (DMI), milk production, milk composition and feed conversion efficiency (FCE) were made over the final five days. Bolding of P value indicates significance ($P < 0.05$). N = Nitrogen.

Measurement	Cow group		Standard error of difference	P value
	High BW/PW	Low BW/PW		
Breeding worth	198	57	16	-
Production worth	319	10	38	-
Live weight (kg)	516	526	34	0.93
DMI (kg DM/cow/d)	16.0	14.8	0.5	0.03
Milk yield (kg/cow/d)	13.6	12.4	0.5	0.03
Milkfat (%)	5.7	5.0	0.2	0.05
Milk protein (%)	4.0	3.4	0.1	<0.001
Milksolids yield (kg/cow/d)	1.32	1.03	0.05	<0.001
Milk N output (g N/cow/d)	85	66	3	<0.001
Milk urea N (mmol/L)	3.88	7.19	0.02	0.04
FCE (g milksolids/kg DM)	83	70	3	0.002

TABLE 2: Feed nitrogen (N) intake and milk, faecal and urinary N concentrations and output measurements from the High and Low BW/PW cows. Values are the means for each group of cows during the five day measurement period. Bolding of P value indicates significance ($P < 0.05$). BW = Breeding worth; PW = Production worth.

Measurement	Cow group		Standard error of difference	P value
	High BW/PW	Low BW/PW		
Feed N intake (gN/cow/d)	388	360	12	0.03
Milk N output (g N/cow/d)	85	66	3	<0.001
Faecal N concentration (%)	2.2	2.2	0.1	0.71
Faecal N output (g N/cow/d)	129	117	6	0.04
Urine N concentration (%)	0.57	0.65	0.03	0.02
Urinary N output (g N/cow/d)	154	165	8	0.04
Distribution of dietary N intake (%)				
Milk	22	18	1	0.003
Faeces	33	33	1	0.60
Urine	40	46	2	0.007
Retained	5	2	3	0.39
Apparent N digestibility (%)	66.7	67.6	0.8	0.62

utilisation, rather it was associated with differences in intake (Trigg & Parr, 1981).

A study by Coleman *et al.* (2010) carried out over three years in the Republic of Ireland compared Holstein-Friesian cows of different genotypes and genetic potential showed some similarities with the milk measurements collected in our experiment. Coleman *et al.* (2010) used an economic breeding index (EBI) which selects for fat and protein yield with a negative weighting on milk volume and includes functional traits such as fertility, health and longevity (Berry *et al.*, 2007). Cows of a North American origin with either High (81.2) or Low (48.8) EBI showed no significant difference in milk yield (6,034 and 5,954 kg/cow respectively). However, there were significant differences between

High and Low cows in milk solids production (456 kg/cow vs 440 kg/cow) although the effect (3.6%) was much smaller than in the present experiment and driven only by a higher milkfat concentration of the High EBI cows. There was no difference in milk protein concentration between the High and Low EBI cows.

Measurements indicated the High BW/PW cows had a lower MUN than Low BW/PW cows (Table 1). Previous research has shown MUN to be a reliable predictor of urinary N excretion by dairy cows (Jonker *et al.*, 1998; Tas, 2006.) and analysis of some previous data also suggest there may be a negative relationship between MUN and NUE in both grass- and TMR-fed cows, although other data have shown no such relationship exists (Tas, 2006). Analysis of our MUN and NUE data from individual cows did not show a significant relationship between MUN and NUE ($P = 0.39$) in this experiment and therefore does not support the use of MUN as a non-invasive indicator of NUE.

Nitrogen partitioning

N intake of the High BW/PW cows was 8% higher than the Low BW/PW cows (Table 2). The proportion of N intake partitioned to milk was higher in the High BW/PW cows (22.0% vs 18.5%) and the milk N output of the High BW/PW cows was 28% higher than the Low BW/PW cows. This difference was almost entirely due to the higher milk protein concentration of the High BW/PW cows (Table 1) rather than any major increase in milk yield. A previous experiment that investigated N partitioning in dairy cows showed that increasing the amount of condensed tannin-containing Lotus (*Lotus coniculatus*) in the cows diet increased the proportion of N intake partitioned to milk. This was a result of increased milk yield as opposed to an increase in milk protein concentration (Woodward *et al.*, 2009).

There was no difference in faecal N concentration between the two groups of cows and High BW/PW cows had a higher faecal N output than Low BW/PW cows but no difference in apparent N digestibility (Table 2). However, the High BW/PW cows had a lower N concentration in the urine. While there was no significant difference in urine output, the difference in N concentration meant High BW/PW cows had lower urinary N output ($P < 0.05$) and less of their N intake was partitioned to urine than in Low BW/PW cows (Table 2).

Summation of the N in the milk, faeces and urine, using individual cow data, accounted for 90 to 99% of daily N intake and there was no significant difference between the High and Low BW/PW cows in unaccounted N (Retained N). Retained N was associated with accretion in body tissue gain, conceptus growth, losses in hair, volatilisation from excreta and errors in measurement of feed eaten, urine, faecal and milk outputs.

Calculation of NUE in terms of milk N output per feed N input showed the High BW/PW cows (NUE = 22.0%) were more efficient ($P < 0.01$) than the Low BW/PW cows (NUE = 18.5%) fed the same diet. The NUE of the High BW/PW cows was low compared to 28% calculated from 580 cows fed 90 different diets, reviewed by Castillo *et al.* (2000), but NUE is affected mostly by dietary CP intake, as well as CP in milk. TMR diets, which formed the basis of some of the studies evaluated by Castillo *et al.* (2000) are usually formulated to provide adequate, but not excessive CP for production, so NUE was high relative to diets containing excess CP, or when fed to cows having a low level of production. However, they also concluded that when N intakes exceeded 400 g/day there was a rapid rise in urinary N excretion, relative to output in milk or faeces. A similar conclusion was modelled by Pacheco and Waghorn (2008) for pastoral feeding and although an intake of 400g N/day will be common for cows fed medium/poor quality pasture, in spring N intakes can exceed 800 g/day, with over 500 g N lost in urine (Waghorn *et al.*, 2007). The higher productivity of cows with High BW/PW, and the results from this study where intakes were measured, suggest cows selected for profitability will excrete a lower proportion of dietary N in urine than low BW/PW cows. A similar response is anticipated when high quality (high N) diets typical of those available in spring are fed.

CONCLUSION

Selection of cows for increased BW/PW to improve production and profitability has also increased the proportion of dietary N retained in milk. In this study, when herbage with only 15% CP

in the DM was fed, the High BW/PW cows ate more, produced more milksolids and excreted a lower proportion of dietary N in the urine than Low BW/PW cows, even though N digestibility was similar in both groups. Selection has benefitted both financial and environmental components of dairy farming because lower urinary N excretion will lessen N loss into ground water and lessen nitrous oxide emissions to the atmosphere. Future measurements will compare BW/PW selections when high quality diets with high N concentrations are fed.

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