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Effect of grain or buffer supplementation on milk solids yield and rumen fermentation patterns of cows grazing highly digestible herbage in spring

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ABSTRACT

Sixteen rumen-fistulated Holstein Friesian cows in early lactation were offered 40 kg herbage dry matter (DM)/cow/day (to ground level). The objective of the experiment was to investigate the economics of feeding cereal grain supplements to cows grazing highly digestible ryegrass herbage in spring and determine the impact of grain feeding on rumen conditions and milk composition. Six kilograms DM of cereal grain were offered to eight cows, while the other 8 cows did not receive grain. Superimposed on these grain supplementation rates were 0 or 300 g sodium bicarbonate in a 2x2 factorial design. The inclusion of grain in the diet reduced herbage intake (from 16.7 - 12.7 kg DM/day, $P<0.01$) and the neutral detergent fibre concentration of the total diet (from 410 g/kg - 325 g/kg DM). Grain feeding reduced milk fat concentration (from 41.7 - 34.3 g/kg, $P<0.05$) and increased milk protein concentration (from 32.8 - 34.6 g/kg, $P<0.05$). Grain feeding depressed the rumen fluid concentration of acetic acid and increased that of propionic acid, resulting in a lipogenic:glucogenic ratio (acetic + butyric:propionic acid ratio) below 3:1 for both grain treatments. The milk responses from cows consuming concentrates with highly digestible herbage in spring were low (-0.4 - 0 kg 4% fat corrected milk/kg DM grain consumed) and did not improve the returns to farmers during the period of feeding. The most profitable use of concentrates is likely to come after spring calving cows have reached their peak and herbage quality begins to decline.

Keywords: grain; herbage; early lactation; dairy; milkfat; volatile fatty acids.

INTRODUCTION

In spring, when cows are grazing highly digestible herbage, responses to supplementary concentrates are usually less than 0.5 kg 4% fat corrected milk (FCM)/kg dry matter (DM) supplement consumed (Stakelum, 1993; Stockdale *et al.*, 1997). In contrast, in summer and early autumn, when herbage quality is lower, marginal responses are often greater than 1.0 kg milk/kg DM supplement (Stockdale *et al.*, 1997). Additional dietary energy is often supplied in early lactation to increase peak milk production and reduce losses in body condition. It would be expected that responses to concentrates would be higher in early, rather than mid or late lactation, due to the higher production potential and energy deficit in cows at this time (Grainger, 1990).

Supplementary feeding with starch-based cereal grains has long been known to reduce rumen pH (Mould & Orskov, 1984). Recent research with stall-fed cows offered Persian clover (*Trifolium resupinatum*) with grain supplements has shown that rumen fluid pH remained below 6 for more than 12 hours per day (Stockdale, 1992). The majority of rumen bacteria display optimal activity and growth within the pH range 6.0- 6.9 (Stewart, 1977). Consequences of sustained low pH in the rumen include the death of cellulolytic bacteria (Stewart, 1977), inefficient rumen fermentation, lactic acidosis and low-milk-fat syndrome. Buffers, such as sodium bicarbonate, are currently included in dairy cow rations to help overcome this depression in rumen pH. Little information, however, is available on the effectiveness of buffers in maintaining rumen pH, rumen fermentation and output of milk by grazing dairy cows offered concentrates twice per day at milking.

This paper reports on an experiment conducted to investigate the effect of grain and/or sodium bicarbonate supplementation on DM intake, milk yield and composition and rumen fermentation characteristics of cows in early lactation grazing highly digestible perennial ryegrass pastures.

MATERIALS AND METHODS

The experiment was conducted in September-October 1998, at Agriculture Victoria Ellinbank (38° 15' S, 145° 93' E), Victoria, Australia. All treatment groups were offered a herbage allowance of 40 kg DM/cow/day (to ground level) of perennial ryegrass-dominant pasture. Sixteen rumen-fistulated Holstein-Friesian dairy cows were allocated to four treatment groups; herbage only (Herb), herbage + 300 g sodium bicarbonate ($NaHCO_3$)(HerbBuff), herbage + 6 kg DM cereal grain (Grain) and herbage + 6 kg DM cereal grain and 300 g $NaHCO_3$ (GrainBuff).

Prior to the commencement of the experiment, the cows grazed together as a single group for 10 days and were offered *ad libitum* herbage and 6 kg DM crushed barley/cow/day to obtain information for allocation of cows to treatment. During this period they were producing (mean ± s.e.m.) 27 ± 0.6 kg milk/cow/day with mean fat and protein concentrations of 38.3 ± 0.71 and 34.6 ± 0.43 g/kg, respectively. They were 29 ± 1.5 days into lactation and had a mean live weight of 521 ± 7 kg.

The experiment lasted 25 days with measurements recorded from days 5 - 25. Each group of four cows grazed within the same paddock, with groups separated by electric fences to control herbage allowances. The daily herbage allowance was offered in approximately equal amounts following each milking and cows had *ad libitum* access to water. Cows on the Grain and GrainBuff treatments received their grain supplementation as two equal feeds in the dairy at milking. The pelleted supplement contained 750 g/kg barley and 250 g/kg wheat. Sodium bicarbonate was placed directly into the rumen via the cannula, in equal amounts, twice daily immediately following milking.

The perennial pasture consisted of (g/kg DM) 830 perennial ryegrass (*Lolium perenne L.*), 105 other grasses

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(cocksfoot, *Dactylis glomerata* L. and winter grass, *Poa annua* L.), five white clover (*Trifolium repens*), 10 weeds and 50 dead material. The average pre-grazing herbage height, as measured using a rising plate meter (Earle and McGowan, 1979), was 8 cm and the average pre-grazing herbage mass was 2.4 t DM/ha. The pastures received an application of 50 kg N/ha 3 weeks prior to grazing.

The cows were milked twice daily at 0730 and 1500 hours and individual milk yields were recorded (ALPRO^{TM} System, Alfa Laval Agri, Sweden). Sub-samples of milk, representative in composition of the milk from the entire milking, were taken, using attachments to the ALPRO milk meter, from individual cows at each milking from Sunday p.m. to Friday a.m. from days 5 - 10 and 12 - 17. Milk fat, protein and lactose concentrations were determined by Milkoscan (Foss Electric, Denmark).

Samples of herbage offered to cows in each grazing area were collected and analysed by wet chemistry methods as described by Dalley *et al.* (1999). On days 9-13 and 16-20, samples of herbage were cut to grazing height from the next days grazing area of each treatment. Following freeze drying the samples were bulked within treatment and week and were ground through a 0.5 mm screen, awaiting alkane analysis.

On day 3, a slow-release alkane capsule containing 8 g of n-Dotriacontane (C32) and 8 g of n-Hexatriacontane (C36) (Captec NZ Ltd.) was inserted into the rumen of each cow. Faecal samples were collected twice daily, from each cow, immediately following milking on days 10-14 and 17-21. On three occasions during the experiment the alkane capsules were removed from each cow, wiped clean, weighed and returned to the rumen. The capsules were then removed following the last faecal sample and the alkane release rate calculated for each cow. The faeces were oven dried at 65°C for 72 hours, ground through a 0.5 mm screen and bulked on a dry weight basis within cow and week. Feed and faecal alkane concentrations and estimated herbage DM intake were determined using the method of Dove & Mayes (1991).

The time spent grazing, ruminating, not chewing, lying and standing was determined by recording each cow's activity, at 10-minute intervals while the cows were in the paddock (Gary *et al.*, 1970). Grazing behaviour was monitored on days 6, 13 and 20 of the experiment.

On two occasions (over days 7-9 and 14-16) rumen fluid (70 to 100 ml) was collected every 4 hours over 48 hours to represent 2-hour intervals over 24 hours. Sampling occurred at 0800, 1200, 1600, 1700, 2000, 2400 h on the first day, 0400, 0900, 1000, 1400, 1800, 2200 h on the second day and 0200, 0600 h on the third day. To minimise possible disturbance to normal grazing behaviour, each group of cows was brought, one at a time, to a portable crush adjacent to the paddock being grazed and was returned to its grazing area immediately after sampling. The pH of the rumen fluid was determined immediately after collection. Subsamples of rumen fluid were collected for subsequent volatile fatty acid (VFA) and ammonia analysis. Ammonia N was determined by a colorimetric method (Lachat Instruments Quick Chem method 18-107-06-1-A) and VFA concentration by gas chromatography using the method of Erwin *et al.* (1961) with minor modifications.

Individual cows were used as the experimental unit. Intake, milk production, rumen parameters, and grazing behaviour were subjected to analysis of variance, using the statistical package Genstat (1993). All analyses included main effects for buffer and grain while the rumen data and grazing observations also included a factor for time. In the absence of significant interactions this data has been omitted from the tables. The marginal response of milk production to supplements was defined as kilogram of 4% fat corrected milk produced/kilogram DM of supplement consumed.

RESULTS

Herbage mass (2.4 ± 0.48 tonne DM/ha) and herbage allowance (40 ± 2 kg DM/cow/day) did not differ between treatments. The nutritive characteristics of the feeds offered are given in Table 1. Herbage intake declined significantly (P< 0.05) when grain was offered (Table 2) resulting in a substitution rate of 0.7-0.8 kg DM/kg DM grain consumed. Adding grain to the diet decreased grazing time and increased resting time (Table 2).

TABLE 1: Composition (g/kg DM) of the herbage and barley-wheat pellet offered to grazing dairy cows in early lactation.

	Herbage	Barley-wheat pellet
In vitro DM digestibility	766	868
Water-soluble carbohydrate	84	35
Crude protein	263	107
Neutral detergent fibre	507	157
Acid detergent fibre	263	50
Lignin	20	7
Phosphorus	4.1	2.8
Potassium	33.2	4.6
Calcium	4.0	0.4
Magnesium	2.6	1.1
Sodium	4.0	0.7

Cows offered grain (Grain and GrainBuff) produced milk with a lower fat and higher protein concentration than those offered herbage only (Herb and HerbBuff; Table 2). The marginal response to supplementary feeding was –0.4-0.0 kg 4% fat corrected milk/kg DM of grain consumed. There was no effect of treatment on milk solids yield and feeding grain did not increase milk income (Table 2). Including buffer in the diet had no effect on milk yield or composition.

Addition of grain to the diet decreased (P<0.05) rumen fluid pH relative to cows consuming herbage only (Table 3). The consumption of grain reduced (P<0.05) rumen fluid concentrations of ammonia-N and acetic acid and increased (P<0.001) that of propionic acid (Table 3). The ratio of lipogenic:glucogenic (acetic + butyric:propionic) acids in the rumen fluid was below 3:1 when grain was included in the diet (Table 3).

DISCUSSION

Supplementation of cows grazing highly digestible perennial herbage in spring with 5-6 kg DM/day cereal grain did not improve milk solids output above that of cows consuming 16-17 kg DM/day of herbage, despite a 2.4 kg/cow/day increase in milk yield. The lack of an improvement in milk solids output can be attributed to a significant reduction in milk-fat concentration when grain was included in the diet. Despite an increase in milk protein yield with grain feeding, this was not sufficient to fully compensate for the reduction in milk-fat yield. The marginal milk

TABLE 2: Herbage and grain intake, milk yield and composition and behaviour of cows (*n*=4 per treatment) grazing highly digestible herbage in spring with or without the addition of cereal grain or buffer.

	Herb	HerbBuff	Grain	GrainBuff	SED Main effect	Significance Levels Grain	Buffer
Intake							
Herbage Intake (kgDM/cow.day)	16.8	16.4	12.6	12.7	0.91	***	NS
Grain Intake (kgDM/cow/day)	-	-	6.1	4.6	0.46	***	NS
Total DMI (kgDM/cow/day)	16.8	16.4	18.7	17.2	0.82	NS	NS
Substitution rate (kg DM/kg DM)[A]	-	-	0.7	0.8	-	-	-
Milk							
Yield (kg/cow.day)	24.9	26.4	27.9	28.2	1.11	NS	NS
4 % fat corrected milk (kg/cow/day)	25.5	27.2	25.2	25.5	0.90	NS	NS
Fat (g/kg)	42.0	41.0	34.4	34.1	2.48	*	NS
Protein (g/kg)	32.8	32.7	35.4	33.7	0.78	*	NS
Lactose (g/kg)	49.5	50.1	51.4	51.2	0.69	NS	NS
Milk solids yield (kg/cow/day)	1.86	2.00	1.95	1.91	0.060	NS	NS
Milk income ($AUD/cow/day)	5.29	5.79	5.72	5.20	0.189	NS	NS
Income – grain costs ($AUD/cow/day)	5.28	5.79	4.45	4.65	0.133	***	*
Grazing behaviour[B]							
Grazing (h/cow/day)	8.3	8.9	6.2	7.1	0.28	***	*
Ruminating (h/cow/day)	5.4	5.1	5.3	5.8	0.27	NS	NS
Not chewing (h/cow/day)	7.2	6.9	9.4	8.0	0.41	**	*

[A]Levels of substitution of grain for herbage are obtained by comparing pasture intakes of unsupplemented groups with those cows offered grain. Substitution is defined as the unit reduction in herbage intake per unit increase in grain intake
[B]Activity was measured for the period when cows were in their treatment areas

TABLE 3: Rumen fluid pH, ammonia and volatile fatty acid concentrations and lipogenic:glucogenic ratio in rumen fluid of cows (*n*=4 per treatment) grazing highly digestible herbage in spring with or without the addition of cereal grain or buffer.

	Herb	HerbBuff	Grain	GrainBuff	SED Main effect	Level of significance Grain	Buffer
Average rumen fluid pH	6.17	6.24	6.07	6.13	0.047	*	NS
Hours below pH 6	8	8	13	10	1.4	*	NS
Rumen fluid ammonia (mmol/l)	20.1	22.9	10.9	13.0	2.40	**	NS
Rumen fluid volatile fatty acids (mmol/l)							
Acetic acid	85.8	91.1	76.0	80.3	4.21	*	NS
Propionic acid	24.4	26.0	35.3	33.1	1.54	***	NS
Butyric acid	15.0	16.2	17.4	15.9	0.98	NS	NS
Total VFA	133.1	144.1	138.5	138.0	4.29	NS	NS
Lipogenic:glucogenic	4.2	4.2	2.7	3.0	0.25	***	NS

response to grain was –0.4 - 0.0 kg 4% fat corrected milk/ kg DM grain consumed. These marginal responses are considerably lower than the 1.1 kg milk/kg DM of concentrates eaten in summer and autumn (Stockdale, 1999) and lower than the 0.5 kg milk/kg DM of concentrate consumed in spring (Stockdale, 1999). It is generally expected that cows at higher levels of production should partition more of any additional feed towards increased milk yield but this was not observed in the current experiment. The most likely explanations for the poor marginal responses include substitution of concentrates for herbage and insufficient effective fibre in the diet to prevent changes in rumen fermentation patterns, which resulted in milk-fat depression.

Responses to grain supplementation are greatest when herbage intake is low (Davison *et al.,* 1982; Stockdale *et al.*, 1987; Stockdale & Trigg, 1989). Unsupplemented herbage intake in the current work was high, hence, the poor marginal responses to grain. Stockdale (1999) concluded that part of the reason for the higher responses with underfed cows on pasture is that mean retention time of digesta in the rumen is likely to be longer. The longer retention time results in rumen pH being maintained at a higher level than when cows are fed better (Stockdale, 1992), resulting in improved rumen function.

Insufficient fibre in the diet reduces rumen pH (Stockdale, 1992) resulting in impaired fibre digestion (Stewart, 1977) and alterations to the ratio of VFAs in rumen fluid (Sutton, 1980). The VFA ratio in the rumen is an important factor in the maintenance of milk-fat concentration. The lipogenic:glucogenic ratio of cows offered cereal grain fell to 2.7. While the addition of sodium bicarbonate increased the ratio to 3, this was still significantly below the 4.2 observed with the two herbage diets. Research in the UK and Australia has demonstrated a rapid decline in milk-fat concentration when the lipogenic:glucogenic ratio of VFAs in the rumen falls below 4 (Sutton *et al.*, 1986; Stockdale *et al.*, 1987). The higher propionic acid concentration in rumen fluid of cows on the Grain and GrainBuff treatments was associated with higher milk protein yield, which partially compensated for the decline in milk-fat yield. Stockdale *et al.* (1990) observed, on both good and poor quality herbage, increases in milk yield and milk protein concentration when additional starch was added to the diet. The importance of these changes in milk composition will be dependent on the differential between the price paid for milk fat and that of milk protein. Under the current payment system used in Victoria there was no immediate financial gain from supplementing 6 kg DM of cereal grain to cows grazing highly digestible pasture in early lactation. When the cost of grain was taken into consideration the income/cow/day for the supplemented cows was less than that of the herbage only cows.

A rapid decline in rumen pH is generally associated with feeding concentrates and is due to the rapid fermentation of starch (Stakelum, 1993). The variation in rumen fluid pH was greatest when cereal grain was offered without a buffer. For all treatments the decline in rumen fluid pH occurred within 2 hours of milking and reached its minimum within 4 hours. Addition of sodium bicarbonate reduced the depression in rumen fluid pH for the 1-2 hours immediately following dosing, however, pH still fell below 6.0 for 10 hours per day on the GrainBuff treatment. Tucker *et al.* (1992) compared sodium bicarbonate with a multi-element buffer on ruminal acid-base status and lactation performance of dairy cows offered a total mixed ration containing 310 g NDF/kg DM. Addition of either buffer in the diet reduced the rumen fluid hydrogen ion concentration from 0 to 6 hours post-feeding but had no effect on milk yield or fat concentration, supporting the findings of the current experiment.

The herbage consumed (410 g NDF/kg DM) had sufficient fibre to meet the National Research Council (1989) requirements of 280 g/kg DM and this is supported by milk-fat concentrations in excess of 40 g/kg observed on both herbage treatments. However, when grain was consumed the dietary NDF concentration declined to 325 g/kg DM and a depression in milk-fat was observed. Requirements for NDF in the diet of grazing dairy cows are unclear, but appear to be in the range 250-400 g/kg DM of total dietary DM. Stockdale *et al.* (1987) reported that milk-fat concentrations declined when the NDF concentration of the diet was below 250 g/kg DM in cows fed irrigated perennial herbage in spring. Mertens (1982) found that dietary NDF concentrations should not be lower than 360 g/kg DM, while Bath *et al.* (1978) and Jorgensen (1984) suggested minimum dietary levels of 280 to 310 g NDF/kg DM for lactating dairy cows.

The milk responses from cows consuming concentrates with highly digestible herbage in spring were low and did not improve the returns to farmers during this period. When cows are well-fed on herbage during spring there appears to be little economic benefit from feeding grain, however as Stockdale *et al*. (1987) indicated underfed cows will respond better to grain feeding. The most profitable use of grain is likely to come after spring-calving cows have reached their peak and herbage quality begins to decline.

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