Fishmeal supplementation to high-producing Jersey cows grazing kikuyu pasture

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Abstract

An experiment examined the benefit of feeding fishmeal to high-producing Jersey cows receiving a maize-based supplement (6 kg/d), while grazing kikuyu pasture in late summer. Three groups of 14 cows received no additional supplement (control), a low fishmeal or a high fishmeal supplement (4 or 8% fishmeal replacing some of the maize). All supplements were iso-energetic. Milk yield increased with the level of fishmeal fed but the response was significant ($P<0.05$) only for the higher level (19.5 *vs* 18.2 kg/d). Milk fat percentage was higher ($P<0.05$) for the low fishmeal treatment (4.18%) than for the control (3.71%), so that yields of 4% fat-corrected milk were higher for both fishmeal treatments than for the control (19.4 and 19.2 *vs* 17.3 kg/d). Milk urea N was higher for the high fishmeal treatment (10.8 mg/dl) than for the control and low fishmeal treatments (9.1 and 9.4 mg/dl). In a simultaneous study, 8 rumen-cannulated cows, grazing with those in the main study, were fed the control and high fishmeal treatments in a crossover design. Ruminal ammonia-N concentration was higher in the cows on the high fishmeal treatment than in the controls (6.52 *vs* 4.74 mg/dl) as was acetate:propionate ratio. While fishmeal supplementation to cows on kikuyu increased milk yields, the economics of this practice will depend on the magnitude of responses as well as relative prices for supplements and milk and the basis for payment. Development of alternative methods of increasing milk production seems worthy of further research.

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Introduction

When only high-quality pasture is fed to dairy cows, milk production is usually limited by the supply of metabolisable energy (ME), but when high levels of grain are fed as supplements and milk production is high, specific amino acids (AA), particularly methionine and lysine, might be the primary limiting factors for milk production (Muller and Fales 1998; Kolver 2003). Hence, on pasture-based dairy farms in the Southern Cape region of South Africa, where only maize and mineral supplements are fed to grazing dairy cows, it is possible that production benefits could be achieved by adding a quality protein source to the supplement.

Responses in milk production or composition from increasing rumen-undegradable protein (RUP) or replacing rumen-degradable protein (RDP) sources with RUP sources in concentrates have been inconsistent (Carruthers *et al.* 1997; Santos *et al.* 1998; Bargo *et al.* 2003). In several studies, RDP sources such as soybean meal, sunflower meal, urea or rapeseed meal have been replaced with RUP sources such as animal protein blend, fishmeal (FM), maize gluten meal, expeller soybean meal, blood meal, feather meal or heat-treated rapeseed meal (Bargo *et al.* 2003). Of these, increases in milk production on pasture were reported by Schroeder and Gagliostro (2000) and Schor and Gagliostro (2001), where the milk response was 6 and 18%, respectively, above the control. The cows in these two studies received 5 and 6 kg concentrate a day, respectively. Fishmeal was the RUP source that most frequently increased milk yield above that achieved with soybean meal and also ranked highest in essential amino acid (EAA) index, indicating that the type of RUP supplement (AA profile) was more important than the amount of RUP (Santos *et al.* 1998). Positive responses to RUP supplementation, above that observed with energy, are most likely in high-yielding, multiparous cows in early lactation, when high levels of grain supplement are fed (Hongerholt and Muller 1998; Schor and Gagliostro 2001).

Pastures of kikuyu (*Pennisetum clandestinum*) oversown with annual ryegrass (*Lolium multiflorum*) are common in the Southern Cape region of South Africa. The former species, adapted to hot climates, is active in summer, complementing the latter, which grows well in winter. This trial was conducted on kikuyu pasture in late summer. The milk production potential of 500 kg cows grazing kikuyu, without supplementation, is approximately 12 L/d in spring, dropping to 6–8 L/d in autumn (Dugmore 1995).

The aim of the study was to determine whether grazing cows, receiving high levels of maize supplementation plus minerals, would respond to the addition of a high-quality protein source, such as FM, to their supplement.

Materials and methods

The study was conducted on the Outeniqua Experimental Farm (22°25′E, 33°57′S; elevation 190 m asl), near George in the Southern Cape. Long-term (39 years) average rainfall in this area is 725 mm per annum. Mean daily maximum and minimum temperatures during the experimental period of the trial were 25 and 16°C, respectively. Average milk production of the farm's herd of 345 cows in milk was 16.7 kg/d in January 2006.

Forty-two high-producing multiparous Jersey cows in early to mid-lactation [body weight, 363 ± 29.2 kg; milk yield, 22.0 ± 1.35 kg/d; parity, 4.2 ± 1.59; days in milk, 65 ± 21.7 days; (mean ± s.d.)] were selected from the herd. They were blocked according to milk yield (over the previous 21 days) and days into lactation and within each block were randomly divided into 3 groups. These 3 groups were randomly allocated to 3 experimental treatments in a randomised complete block design.

The cows strip-grazed kikuyu pasture (fertilised with 56 kg/ha N as limestone ammonium nitrate after each grazing) and were moved to a new strip twice daily after each milking. The cows were milked at 06.00 h and 14.30 h, and grazed throughout (except for the milking times) as a single herd to ensure equal pasture allocation. The mean pasture allowance was 13 kg dry matter (DM) per cow per day above 3 cm pasture height. A rising plate meter (RPM; Filip's folding plate pasture meter, Jenquip, Rd 5, Fielding, New Zealand) was used to estimate the amount of pasture DM available per ha and the grazing area allocated to the cows was calculated accordingly. The RPM was calibrated by selecting 3 low, medium and high pasture heights, measuring the pasture height with the RPM and cutting the grass below the plate to a height of 3 cm above the ground. Each sample was weighed and dried at 60°C for 72 hours to determine the amount of DM present, which was extrapolated to kg/ha DM. This was done weekly and the data composited. A linear regression equation [$Y = aH + b$, where Y = pasture mass in kg/ha DM and H = RPM reading] was fitted to the data using the LINEST function in Microsoft® Excel which resulted in the equation $Y = 54H + 764$ ($R^2 = 0.4$; n = 72).

In addition to the pasture, each cow received 6 kg (5.5 kg DM) of pelleted concentrate per day, divided into 2 equal portions and fed in the milking parlour. Each of the 3 groups of cows received a different concentrate formulated to be iso-energetic (Table 1). The pellets of the cows on the control treatment contained no FM. For the 2 FM treatments, some of the maize was replaced by FM: 4% (240 g FM/cow/d) for the low FM treatment and 8% (480 g FM/cow/d) for the high FM treatment with Megalac (a rumen protected fat; Church and Dwight Co., Inc., 469 N. Harrison St., Princeton, NJ 08543-5297) added to make all supplements iso-caloric.

Representative samples of pasture and concentrate were taken weekly, milled through a 1 mm screen and analysed at Nutrilab (Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria) for DM, ash, ether extract (EE), calcium, P (AOAC 2000), CP (using a Leco N analyser, model FP-428, Leco Corporation, St Joseph, MI, USA), neutral detergent fibre (NDF; Robertson and van Soest 1981), acid detergent fibre (ADF; Goering and van Soest 1970), *in vitro* organic matter digestibility (IVOMD; Tilley and Terry 1963 as modified by Engels and van der Merwe 1967), gross energy (GE; MC — 1000 Modular Calorimeter, Operators Manual) and AA composition (with the PICOTag method of Bidlingmeyer *et al.* 1984 using a Waters HPLC with two Model 510 pumps, UV protector

Model 440, autosampler Model 712 and Waters Millennium 32 software). Metabolisable energy was calculated with the following formula: ME (MJ/kg DM) = 0.82 × (GE × IVOMD) (Robinson *et al.* 2004).

After an adaptation period of 10 days on the different rations, milk yield was measured in the milking parlour for 50 days (days 11 to 60 of the trial). Composite milk samples (ratio 9 ml: 15 ml, afternoon:morning milking) were taken every second week and analysed for fat, protein, lactose and milk urea N (MUN) at Lactolab Pty (Ltd) using the Milkoscan FT 6000 (Foss Electric, Denmark). Fat-corrected milk (FCM) yield was calculated using the following formula: 4% FCM = 0.4 × kg milk + 15 × kg milk fat (NRC 2001).

At both the beginning and the end of the trial, the cows were weighed unfasted on 2 consecutive days and the mean of these 2 weights calculated. Body condition score (BCS) was determined on the first of these 2 days using a 5-point system, where 1 is thin and 5 is fat (Wildman *et al.* 1982).

A simultaneous rumen study was conducted using 8 Jersey cows, from the same herd, fitted with rumen cannulae. These cows grazed, were milked and received concentrate with the cows of the production study. A cross-over design was used. In the initial stage, 4 cows (chosen at random) received the control treatment and the remaining 4 received the high FM treatment. After an adaptation period of 14 days, the cows were fitted with automated pH meters with data loggers (WTW pH 340i pH meter/data logger with a WTW SenTix 41 pH electrode) so that ruminal pH could be monitored at 10-minute intervals throughout the day. The electrode was placed in the rumen via the cannula and connected to the data logger that was strapped on like a saddle. Four pH meters with data loggers were alternated between the cows so that in the end each cow was monitored for a total of 4 days. Samples of ruminal fluid were taken from all 8 cows at 04.00 h, 12.00 h and 20.00 h on Day 27 and at 08.00 h, 16.00 h and 00.00 h on Day 28 to provide samples representing every 4 hours of the day. From each sample, 30 ml of rumen filtrate was preserved with 5 ml of 50% H_2SO_4 and frozen for ammonia-N (NH_3-N) analysis (De Bruin 1995) and 20 ml of rumen filtrate was preserved with 4 ml of 25% H_3PO_4 and frozen for

Table 1. Ingredient and chemical composition of the concentrate pellets used for the 3 experimental treatments.

Parameter	Control	Low FM	High FM
Ingredient composition		(% DM)	
Maize meal	88.75	84.1	78.45
Fishmeal (FM)	0	4.0	8.0
Megalac[1]	0	0.65	1.3
Molasses	6.8	6.8	6.8
MonoCaP	1.3	1.3	1.3
Feed lime	1.8	1.8	1.8
Salt	0.5	0.5	0.5
MgO	0.5	0.5	0.5
Premix[2]	0.35	0.35	0.35
Chemical composition[3]			
DM % (as is)	92.4	91.4	91.5
ME (MJ/kg DM)[4]	13.6	13.8	13.6
		(% DM)	
OM	94.0	92.1	91.4
CP	7.7	10.1	12.7
NDF	13.9	14.9	17.5
ADF	3.6	3.4	3.6
IVOMD	95.8	95.8	94.1
EE	2.3	2.7	3.0
Ca	1.23	1.53	2.02
P	0.53	0.63	0.81
Ca: P	2.30:1	2.43:1	2.48:1

[1] Rumen protected fat (Church and Dwight Co., Inc., Princeton, NJ).
[2] Premix (Lactating Cow (Organic); DSM Nutritional Products South Africa Pty Ltd.) contained 7.23% Mn, 7.50% Zn, 1.83% Cu, 0.11% Co, 0.14% I, 0.03% Se (1%), 1.28% organic Mn, 2.00% organic Zn, 0.32% organic Cu, 0.01% organic Se, 5% Rumensin (20%), 3.5% Stafac 500 and provided 96 250 IU of vitamin A, 28 875 IU of vitamin D3 and 577.5 mg of vitamin E/cow/d.
[3] n = 1.
[4] ME = 0.82 × (GE × IVOMD) (Robinson *et al.* 2004).

volatile fatty acid (VFA) analysis (Beauchemin *et al.* 2003). These were analysed for NH_3-N (Broderick and Kang 1980) and VFA (acetic, propionic, butyric, iso-butyric and valeric acids; Webb 1994, with modifications) at Nutrilab.

On Day 30 of the trial, the cannulated cows were switched to the opposite experimental treatment (those that were on the control treatment received the high FM treatment and vice versa) so that all 8 cows received both treatments during the study. After an adaptation period of 12 days, monitoring of rumen pH commenced again as above. Samples of rumen fluid were taken at 00.00 h on Day 53, 08.00 h and 16.00 h on Day 54 and 04.00 h, 12.00 h and 20.00 h on Day 55.

An analysis of variance with the ANOVA model (SAS 2001) was used to test for differences between the experimental treatments in terms of milk yield and composition, FCM, change in BW and BCS and mean daily ruminal pH, NH_3-N and VFA levels. Significance of difference was determined using Duncan's test (Samuels 1989).

Results

Chemical analyses of the pasture samples (Table 2) showed that available pasture contained crude protein levels of 22.1%, NDF of 60% and IVOMD of 69.9%, with 10MJ ME/kg. The CP concentrations of the supplements were 7.7, 10.1 and 12.7% for the control, low FM and high FM treatments, respectively. Although the EE increased slightly with the inclusion of FM and Megalac, the ME of the 3 concentrates was similar. The supplements contained 5.2 g/kg DM lysine and 1.7 g/kg DM methionine (63 g lysine and 21 g methionine per day) for the control treatment, 5.9 g/kg DM lysine and 1.9 g/kg DM methionine (73 g lysine and 24 g methionine per day) for the low FM treatment and 6.6 g/kg DM lysine and 2.2 g/kg DM methionine (81 g lysine and 26 g methionine per day) for the high FM treatment.

Milk yield increased with increasing level of fishmeal fed but differences were significant ($P<0.05$) only for the high level of fishmeal (Table 3). However, cows on the low level of fishmeal had higher ($P<0.05$) milk fat percentage than controls, so that 4% FCM yields for both fishmeal treatments were 11.5% higher ($P<0.01$) than for the control. Fat yields for both fishmeal treatments were higher (13–18%) than for the control. Milk protein yields were higher ($P<0.05$) for the fishmeal treatments than for the control, but there was no treatment effect on milk protein percentage ($P>0.10$; Table 3). Milk lactose percentage was higher in both FM treatments than in the control ($P<0.01$).

Table 2. Chemical composition (mean ± s.d.) of the kikuyu pasture grazed by the cows during the trial.

Nutrient[1]	Mean composition
DM (% as is)	15.7 ± 26.2[3]
ME (MJ/kg DM)[2]	10.0 ± 0.28[4]
	(% DM)
OM	88.2 ± 15.8[3]
CP	22.1 ± 30.7[3]
NDF	60.3 ± 45.1[3]
ADF	30.5 ± 35.0[3]
IVOMD	69.9 ± 45.3[3]
EE	2.1 ± 2.1[4]
Ca	0.37 ± 0.32[4]
P	0.35 ± 0.27[4]
Ca: P	1.08:1 ± 0.054[4]

[1] DM — Dry matter; OM — Organic matter; CP — Crude protein; NDF — Neutral detergent fibre; ADF — Acid detergent fibre; IVOMD — *In vitro* organic matter digestibility; EE — Ether extract.
[2] ME = 0.82 × (GE × IVOMD) (Robinson *et al.* 2004).
[3] n = 8.
[4] n = 3.

Cows on all treatments made small weight gains over the period of the study, with no differences between treatments (Table 3). Body condition scores remained virtually constant.

Mean daily ruminal pH (Table 4) did not differ between the control and high FM treatments ($P>0.05$), but ruminal NH_3-N concentration was higher for the cows on the high FM treatment than for the controls ($P<0.05$). Total VFA concentrations were similar on the 2 treatments ($P>0.05$), but the molar proportions (mol/100 mol total VFA) of acetate and butyrate and the acetate:propionate ratio were higher on the high FM treatment than in the controls ($P<0.05$ for acetate; and $P<0.01$ for butyrate and acetate:propionate ratio), while the molar proportion of propionate was higher in the controls ($P<0.01$).

Discussion

This study has shown that providing a fishmeal supplement to Jersey cows receiving a grain-based supplement while grazing kikuyu pasture in early lactation can increase milk production. Assuming the RUP of the FM was 66% of CP (NRC 2001), each successive increment of FM would have

Table 3. Effects of fishmeal supplementation on mean milk yield, milk composition, body weight and body condition score[1] of cows grazing kikuyu pasture and receiving 5.5 kg/d supplement DM (n = 14).

Parameter	Experimental treatment[2]			s.e.m.
	Control	Low FM	High FM	
Milk yield (kg/d)	18.2a[7]	18.9ab	19.5b	0.30
4% FCM[3] (kg/d)	17.3a	19.4b	19.2b	0.30
Fat (%)	3.71a	4.18b	3.91ab	0.101
Fat yield (kg/d)	0.67a	0.79b	0.76b	0.017
Protein (%)	3.30	3.41	3.34	0.042
Protein yield (kg/d)	0.60a	0.64b	0.65b	0.012
Lactose (%)	4.43a	4.60b	4.63b	0.038
MUN[4] (mg/dl)	9.09a	9.44a	10.80b	0.260
BW[5] beginning (kg)	364	374	352	7.3
BW end (kg)	376	384	360	7.9
BW change (kg)	+12	+10	+8	3.0
BCS[6] beginning	2.2	2.3	2.3	0.08
BCS end	2.2	2.2	2.3	0.05
BCS change	0	–0.1	0	0.08

[1] Five-point system where 1 is thin and 5 is fat (Wildman *et al.* 1982).
[2] Control = supplement containing no fishmeal (FM); Low FM = supplement containing 4% FM; High FM = supplement containing 8% FM.
[3] FCM — fat-corrected milk. [4] MUN — Milk urea N. [5] BW — body weight; [6] BCS — body condition score.
[7] Means in the same row followed by different letters differ (P<0.05).

Table 4. Effects of fishmeal (FM) supplementation on mean daily ruminal pH, ammonia-N (NH_3-N) and volatile fatty acid (VFA) concentrations of cows grazing kikuyu pasture and receiving 5.5 kg/d supplement DM (n = 8).

Parameter	Experimental treatment[1]		s.e.m.
	Control	High FM	
pH	6.15	6.15	0.030
NH_3-N (mg/dl)	4.74a[2]	6.52b	0.294
Total VFA (mmol/L)	118.6	118.5	0.94
Acetate (mol/100 mol)	65.8a	67.6b	0.36
Propionate (mol/100 mol)	23.2b	20.3a	0.54
Butyrate (mol/100 mol)	9.1a	10.6b	0.24
Acetate:propionate	2.88:1a	3.37:1b	0.083:1

[1] Control = supplement containing no FM; High FM = supplement containing 8% FM.
[2] Means in the same row followed by different letters differ (P<0.05).

supplied an additional 100 g/d RUP to the diet and produced a response of 0.6–0.7 kg milk. This response was similar to the average increase in milk production of 0.8 kg/d for each 100 g/d of RUP supplementation, reported by Bargo *et al.* (2003) in a review of responses to supplements by dairy cows.

However, responses in terms of fat production did not follow a similar trend. Since fat production was similar on both fishmeal treatments and greater than that on the control, 4% FCM yields were similar at both levels of fishmeal supplement, indicating that addition of 240 g/cow/d of fishmeal to a maize-mineral concentrate would produce maximum yield of 4% FCM. Presumably, energy became the primary limiting nutrient at this point. Since fat percentages in milk on the two fishmeal treatments were different and higher than that of the control, payment for milk would need to be based on both quantity and quality for a farmer to obtain the full financial benefit of increasing the CP levels in supplements for cows.

The increase in milk fat percentage in the low FM treatment supported the findings of McCormick *et al.* (2001), who increased milk fat percentage (3.34 *vs* 3.11%) by increasing the CP concentration (22.8 *vs* 16.6% CP) in the supplement for Holstein cows grazing annual ryegrass-oat pasture. However, it contrasts with the suggestion of Schroeder and Gagliostro (2000) that feeding FM could reduce milk fat percentage. The latter authors attributed this to high concentrations of unsaturated long-chain fatty acids in

FM or a reduction in acetate:propionate ratio in ruminal fluid negatively affecting milk fat. Unfortunately acetate:propionate ratios in cows receiving the lower level of FM were not measured in this trial, but the acetate:propionate ratio (Table 4) was higher for the cows on the high FM treatment than for the controls. These effects on molar proportions of VFA are in agreement with the study of Broderick (1992), where supplementation with FM (*vs* soybean meal) lowered rumen propionate levels and increased the acetate:propionate ratio ($P<0.05$). The levels were in the expected range for cows on a pasture-concentrate feeding system (Bargo *et al.* 2002a; 2002b; 2003).

The 4% FCM yield response to FM supplementation would be a reflection of increased intake of CP (both RDP and RUP). Rumen degradable protein was low for cows in the control group as indicated by the low ruminal NH_3-N (4.74 mg/dl) concentration, which was below the minimum level of 5 mg/dl for maximum microbial protein synthesis (Satter and Slyter 1974). At the higher level of FM supplementation, ruminal NH_3-N concentration increased to 6.52 mg/dl, indicating that more N was available for the rumen microbes. Previous studies (Jones-Endsley *et al.* 1997; Bargo *et al.* 2001) reported higher rumen NH_3-N concentrations when the concentrate contained more CP. The differences in ruminal NH_3-N levels on the various treatments are reflected in the increasing MUN levels as the level of FM in the supplements increased (Table 3). MUN level at the higher FM level was still at the lower end of the target range of 10–16 mg/dl (Jonker *et al.* 1999), while it was outside the range on the other two treatments.

The CPM Dairy model (Version 3.0.7a; Cornell University, Ithaca, NY, University of Pennsylvania, Philadelphia, PA; Willam H. Miner Agricultural Institute, Chazy, NY) predicted DM intake (DMI) to be higher in the cows on the two FM treatments. The higher pasture intake would have contributed to the production response as well as being driven by the higher milk production, since cows consume feed to meet their energy needs (NRC 2001).

The higher milk lactose percentage in the FM treatments than in the control is in agreement with the results of Tesfa *et al.* (1995), where milk lactose was lower in cows supplemented with a cereal by-product-based concentrate (12.4% CP) than in cows given additional N, in the form of urea or rapeseed meal (non-heat-treated or heat-treated), in their concentrates (15.0–15.6% CP). There is no biological explanation for the increase in the lactose percentage.

The absence of any effect on body weight or body condition score is in agreement with the study of Jones-Endsley *et al.* (1997), where increasing the amount of CP in the concentrate did not affect BW or BCS. It appears that increased feed intake was sufficient to provide nutrients for the increased milk yields, without drawing on body reserves.

No difference in ruminal pH was expected, since changing the level and source of protein did not affect ruminal pH in previous studies (Bargo *et al.* 2003). Although the pH varied throughout the day, it was never suboptimal (below 5.8, the level at which cows start experiencing subclinical acidosis; Graf *et al.* 2005).

If the inclusion of FM in the supplement is to be economical (increase profit), the extra revenue from the additional milk would have to be greater than the additional cost. In March 2007, maize, FM and Megalac, delivered in George, cost R1990, R6396 and R5468/tonne, respectively, so that the supplement for the low FM treatment cost R1.19/cow/d more than for the control. Since milk solids affect milk price, a more valid comparison can be made if FCM is used rather than milk yield *per se*. The cows on the low FM treatment produced 2.1 kg/d more 4% FCM than the cows on the control treatment. Assuming a milk price of R3.00/kg (a realistic price for milk with 4% fat in South Africa at the time of writing), this would result in an additional profit of R5.11/cow/d (and about R3.32 at the high level of FM). Thus, fishmeal supplementation to cows on kikuyu pasture would have been profitable under that scenario. However, in any given situation, profitability would depend on the responses obtained, the relative prices of the feed ingredients and the price of milk (including the basis for determining milk price, *i.e.*, volume only or volume + composition).

The overall low milk production in the study was related to the 'autumn slump', common for kikuyu pasture in February (end of summer) (Henning *et al.* 1995), with low intake of pasture owing to high NDF as well as high temperatures (NRC 2001). For cows grazing kikuyu pasture, stimulating pasture intake by enhanced pasture management might be more rewarding than changing the supplement to achieve a similar outcome, since milk production appeared to be limited by both ME and CP. For example, if the pasture is grazed at the right stage of maturity, the NDF percentage could be lower and hence less restrictive to the intake capacity of the cow.

Conclusions

The results obtained in this study indicate the potential for farmers to increase production and profitability by adding low levels of fishmeal to the concentrate supplement for dairy cows grazing kikuyu pastures in summer. However, unless payment for milk is based on both quality and quantity, the full financial benefit would not be obtained. There appears to be a ceiling on the level of response possible and further work is needed to lift potential milk production levels from these systems. The interactions between the supply of energy, RUP and RDP are an area for future research.

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