The effect of concentrate supplementation on the productivity of grazing Jersey cows on a pasture based system

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Abstract

The effect of concentrate feeding on milk production, milk composition, live weight, condition score and intercalving period of 60 Jersey cows grazing high quality pastures over two lactations was determined. Cows were fed at a no (NC), low (LC), medium (MC) or high (HC) level of concentrate. All cows received a mineral supplement of 300 g/day. The LC, MC and HC groups were fed an energy concentrate at 3, 6 and 9 kg/day, respectively from day 1 to day 150 of lactation followed by 1.5, 3 and 4.5 kg of energy concentrate per day from day 151 to day 300 of lactation. The energy concentrate consisted of 10.6% whole cottonseed, 42.1% rolled maize, 42.1% rolled wheat, 4.2% molasses, 0.5% feedlime and 0.5% salt on a dry matter (DM) basis. A protein concentrate consisting of 76.5% cotton oil cake and 23.5% fish meal was fed at 0.5, 1 and 1.5 kg per day to the LC, MC and HC group respectively from days 1 to 105 of lactation. The lactating cows grazed pasture allocated at 20 kg DM/cow/ day consisting of 43% perennial ryegrass/clover, 24% annual ryegrass/oats, 14% lucerne, 15% kikuyu and 4% other pastures during the experimental period. The fat corrected milk (FCM) production per lactation of cows fed NC (0 kg/day), LC (2.4 kg/day), MC (4.8 kg/day) and HC (7.2 kg/day) was 3741, 4645, 4868 and 5282 kg (s.e.m. = 146), respectively. Cows fed the high level of concentrate (HC) produced significantly more FCM and butterfat than cows on the other treatments. The FCM production of cows on the LC and MC treatments did not differ from each other and both produced more FCM than the control treatment. Cows produced 1.25, 0.78 and 0.54 L of FCM for each kg of concentrate fed at the LC, MC, and HC levels of concentrate feeding over two lactations. Concentrate feeding had no significant effect on milk composition, live weight and intercalving period of cows. The condition score of cows improved as the level of concentrate feeding increased.

Keywords: Milk production, milk composition, grazing, intercalving period, condition score, live weight change, pasture quality
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Introduction

Pasture is the base for profitable milk production in the Southern Cape region of South Africa. Energy intake is the first limiting factor for milk production in cows grazing on pasture (Kolver, 2003), including perennial ryegrass/white clover, annual ryegrass and oat pastures. Concentrates are supplemented to cows grazing on pasture to increase the stocking rate, increase milk production, maintain body condition and improve the profitability of dairy farming (Bargo *et al*., 2003). The cost of pasture in the Southern Cape may vary from R 0.20 to R 0.60 per kg dry matter (DM) and that of dairy concentrate from R 0.80 to R 1.80 per kg DM. Concentrates often constitute 66% of the total feed cost and pasture 34% (W.J. Burger; Personal communication, Outeniqua Experimental Farm, P.O. Box 249, George, 6530). The level of concentrate feeding and the associated milk production response have a major effect on the profitability of pasture based dairy farming. It is therefore important to determine the optimum level of concentrate supplementation. The milk response to concentrate fed to cows on a pasture based system is affected by pasture quality, pasture allowance, nutritional value of the concentrate, level of concentrate feeding and the genetics of the cow (Bargo *et al*., 2003). The milk response per kg concentrate fed tends to decline as pasture allowance is increased (Grainer & Mathews, 1989) and the level of concentrate feeding is increased (Robaina *et al*., 1998). A high pasture allowance results in poor pasture utilization, lower stocking rates and reduced profit per hectare. The substitution rate by which concentrate replaces pasture is greater at a high pasture allowance and therefore the response to concentrate feeding will be lower (Bargo, 2002).

King *et al*. (1990) found that cows produced only 0.6 kg milk/kg of concentrate, when fed at 3.5

kg/cow/day. The aim of this study was to determine the long-term effect of concentrate supplementation on milk yield, milk composition, live weight, condition score and intercalving period of Jersey cows grazing on a pasture based system in the Southern Cape region of South Africa.

Materials and Methods

The study was done at the Outeniqua Experimental farm, George (longitude 22º 25' E, latitude 33º 57' S, altitude 190 m). The long term (30 year) average rainfall is 715 mm per annum. Monthly rainfall is 60 mm, 64 mm, 52 mm and 62 mm during summer, autumn, winter and spring, respectively. Pasture was irrigated at 750 mm per annum according to tensiometer readings, to keep tensiometer readings between –10 and –25 kPa. Average daily maximum and minimum temperatures are 24 and 15 °C during summer, 22 and 12 °C during autumn, 19 and 7 °C during winter and 20 and 11 °C during spring, respectively (Weather SA, 2004).

Sixty Jersey cows were randomly allocated to four treatments (15 cows per treatment). Cows remained in their groups for two consecutive lactations. Heifers were assigned to groups at random by order of calving. Multiparous cows were blocked according to milk yield in their most recently completed lactation and then randomly assigned to treatments as they calved. Calving took place over an extended period of six months. All cows were dried up 60 days before the expected calving date. Milk production was measured daily over 300 days of lactation. Milk samples were taken monthly, preserved with sodium dichromate, stored in containers and sent to the laboratory to be analysed for milk fat and protein content with a 605 Milko Scan analyzer, a mid-range infrared spectrophotometer (IDF, 1996). The pasture grazed during the three years of the study consisted of 43% perennial ryegrass/clover, 24% annual ryegrass/oats, 14% lucerne, 15% kikuyu and 4% other pastures. Twenty kg of pasture DM was offered per cow per day to ensure that sufficient pasture was available. Pasture yield before grazing was estimated by cutting 10 representative randomly selected quadrants to ground level. Samples were oven-dried at 60 ºC for 72 h to determine the DM content, milled through a 1 mm sieve and stored in plastic jars pending chemical analyses. *In vitro* organic matter digestibility (IVOMD) was determined according to Tilley & Terry (1963), neutral detergent fibre (NDF) and acid detergent fibre (ADF) according to Van Soest *et al*. (1991). The metabolisable energy (ME) content was calculated according to the ARC (1984) and assumed to be equal to 18.4 x IVOMD x 0.81. Total nitrogen was determined by the Kjeldahl method (AOAC, 1995). The minerals Ca, P, Na, K, Mg, Fe, Cu, Zn and Mn were determined using an inductively coupled plasma dry ashing method (ALASA, dry ashing 6.1.1, RevA/98) with an Iris Advantage Thermo elemental instrument according to Giron (1973). Selenium was determined using a Perkin-Elmer Model LS-2B Filter Fluorimeter (Koh & Benson, 1993). Cows were fed a no (NC), low (LC), medium (MC) or high (HC) level of concentrate. All cows received a mineral/vitamin supplement of 300 g /day to supply 36 g Ca, 24 g P, 21 g Mg, 240 mg Fe,15 mg Co, 225 mg Cu, 300 mg Mn, 450 mg Zn, 7.5 mg I, 90 000 IU vitamin A and 30 IU vitamin E per cow per day. The LC, MC and HC groups were fed an energy concentrate (13 MJ ME/kg DM, 130 g CP/kg DM) at 3, 6 and 9 kg/day respectively from day 1 to day 150 of lactation followed by 1.5, 3 and 4.5 kg energy concentrate per day from day 151 to day 300 of lactation. The energy concentrate consisted of 10.6% whole cottonseed, 42.1% rolled maize, 42.1% rolled wheat, 4.2% molasses, 0.5% feedlime and 0.5% NaCl on a DM basis. A protein concentrate was fed at 0.5, 1 and 1.5 kg per day to the LC, MC and HC group, respectively, from day 1 to day 105 of lactation, to supplement quality protein during early lactation. The protein concentrate (10.6 MJ ME/kg DM, 480 g CP/kg DM) consisted of 76.5% cotton oil cake and 23.6% fish meal on a DM basis. The average amount of concentrate fed per day over the lactation was 0, 2.4, 4.8 and 7.2 kg for the NC, LC, MC and HC, respectively. Milk yield was measured daily and milk composition, live weight and condition score (Mulvany, 1977) were determined monthly. All the cows grazed as one group. Cows were inseminated when on heat after 55 days in milk.

Analysis of variance was done, using SAS (1999) and a nonlinear regression was fitted to predict fat corrected milk production over a 300 day lactation: $Y = a + bx^{0.5}$.

Results and Discussion

The mean chemical composition of the different types of pastures grazed by the lactating cows during the experimental period is given in Tables 1 and 2. The average crude protein (CP) content of annual ryegrass, perennial ryegrass/clover and lucerne was higher than the nutritional requirement of high producing dairy cows. The CP content of annual ryegrass varied from 136 to 310 g /kg DM. This large variation in CP indicates that regular analysis of grass samples should be done and the CP content of the concentrate should be adjusted accordingly to ensure that the protein requirement of cows is met. The DM content of the lucerne grazing was higher and the NDF content lower than that of annual ryegrass and perennial ryegrass/clover pasture, which makes it an excellent pasture crop. Kikuyu had the lowest digestibility (9.3 MJ ME/kg DM), the highest NDF content of 635 g/kg DM and a Ca to P ratio of 1.3: 1. These are similar values to those reported by Reeves *et al*. (1996). The average potassium (K) concentration of kikuyu, annual ryegrass and perennial ryegrass/clover was higher than 30 g/kg DM. This high K concentration may lead to a reduction in Ca and Mg absorption (Underwood, 1981).

Table 1 Mean (± s.d.) seasonal chemical composition (DM basis) of pastures at point of grazing, sampled during the experimental period over three years (n = 12)

	Perennial ryegrass/clover			
Nutrient composition	Summer	Autumn	Winter	Spring
DM (g/kg as is)	163 ± 17.6	150 ± 16.0	153 ± 18.4	145 ± 9.1
Ash (g/ kg)	90 ± 15.3	112 ± 9.9	110 ± 4.4	101 ± 12.5
CP(g/kg)	211 ± 25.3	236 ± 16.4	258 ± 26.1	207 ± 44.7
ME (MJ/kg)	9.9 ± 0.29	9.6 ± 0.76	10.7 ± 0.77	10.6 ± 0.56
NDF (g/kg)	476 ± 45.9	519 ± 69.4	436 ± 69.5	437 ± 41.3
ADF (g/kg)	301 ± 13.7	306 ± 21.1	256 ± 26.3	285 ± 28.5
	Annual ryegrass			
Nutrient composition	Summer	Autumn	Winter	Spring
DM (g/kg as is)	-	119 ± 18.8	140 ± 22.8	147 ± 36.2
Ash (g/ kg)	-	115 ± 15.0	100 ± 16.5	871 ± 17.6
CP (g/kg)	-	256 ± 54.9	251 ± 62.7	180 ± 45.9
ME (MJ/kg)	-	9.5 ± 1.37	10.8 ± 0.91	10.9 ± 0.63
NDF (g/kg)	-	510 ± 85.1	450 ± 59.2	490 ± 62.3
ADF (g/kg)	-	290 ± 35.3	241 ± 34.4	280 ± 41.2
	Kikuyu			
Nutrient composition	Summer	Autumn	Winter	Spring
DM (g/kg as is)	187 ± 48.6	159 ± 44.1	168 ± 28.5	181 ± 31.7
Ash (g/ kg)	88 ± 26.0	99 ± 16.5	106 ± 10.2	96 ± 13.7
CP (g/kg)	157 ± 44.0	196 ± 57.1	218 ± 51.4	176 ± 42.2
ME (MJ/kg)	8.7 ± 0.51	8.4 ± 0.60	9.3 ± 1.28	9.7 ± 0.93
NDF (g/kg)	682 ± 57.2	670 ± 61.1	592 ± 115.3	598 ± 78.9
ADF (g/kg)	322 ± 39.3	313 ± 32.2	271 ± 39.4	290 ± 291
	Lucerne			
Nutrient composition	Summer	Autumn	Winter	Spring
DM (g/kg as is)	182 ± 28.8	188 ± 28.0	200 ± 17.4	199 ± 17.9
Ash (g/ kg)	74 ± 14.0	97 ± 27.8	86 ± 20.2	73 ± 12.2
CP (g/kg)	215 ± 32.5	246 ± 36.1	257 ± 25.6	222 ± 41.7
ME (MJ/kg)	9.3 ± 0.39	9.3 ± 0.81	10.6 ± 0.87	10.1 ± 0.51
NDF (g/kg)	417 ± 52.8	430 ± 39.1	371 ± 62.1	410 ± 48.7
ADF (g/kg)	321 ± 31.2	311 ± 28.2	262 ± 36.3	312 ± 32.3

DM - Dry Matter; CP - Crude protein; ME - Metabolisable energy; NDF - Neutral detergent fibre; ADF - Acid detergent fibre

The milk production, milk composition, live weight, condition score and intercalving period of cows fed different levels of concentrate over two lactations are presented in Table 3. The prediction of FCM production over a 300 day lactation using a non-linear equation is shown in Table 4. The milk production increased as the level of concentrate feeding increased. Cows fed the high level of concentrate (HC) produced significantly more fat corrected milk (FCM) and butterfat than cows on all the other treatments.

The yield of FCM, butterfat and protein on the NC treatment was lower than that of the LC and the MC treatments. Feeding of each additional kg of concentrate resulted in production of 1.25, 0.78 and 0.54 kg FCM

Table 2 Mean (± s.d.) mineral composition (DM basis) of pastures at point of grazing sampled during the experimental period of three years

Mineral	Kikuyu n = 20	Ryegrass n = 24	Ryegrass / clover n = 24	Lucerne n = 20
Ca (g/kg)	4.3 ± 1.2	6.7 ± 2.1	8.8 ± 2.2	11.9 ± 2.7
P (g/kg)	3.3 ± 0.8	3.6 ± 0.8	4.0 ± 1.0	3.3 ± 1.0
Mg (g/kg)	3.6 ± 0.8	3.6 ± 1.1	4.4 ± 1.4	3.7 ± 1.5
Na (g/kg)	2.8 ± 2.3	8.9 ± 6.2	6.5 ± 3.7	3.1 ± 1.1
K (g/kg)	30.4 ± 9.4	33.9 ± 17.1	30.1 ± 11.6	23.6 ± 11.1
Cu (mg/kg)	8.0 ± 2.6	6.9 ± 1.6	8.1 ± 1.7	8.0 ± 1.9
Zn (mg/kg)	43.9 ± 7.3	42.9 ± 11.6	44.4 ± 7.1	42.1 ± 8.0
Mn (mg/kg)	79.8 ± 36.4	60.5 ± 20.1	63.4 ± 24.5	43.3 ± 16.1
Fe (mg/kg)	196 ± 133	194 ± 90	360 ± 215	149 ± 72

Table 3 Milk production, milk composition, live weight, condition score and intercalving period of cows fed different levels of concentrates over two lactations (n = 26)

Parameters	Concentrate level [f] NC	LC	MC	HC	s.e.m.[d]
Concentrate fed/lactation (kg)	0	720	1440	2160	
Milk production over 300 days (kg)	3543 [c]	4356 [b]	4565 [ab]	4885 [a]	142.3
FCM[e] over 300 days(kg)	3742 [c]	4645 [b]	4868 [b]	5282 [a]	146.5
FCM kg/kg concentrate	-	1.25	0.78	0.54	
Butterfat (kg)	154 [c]	194 [b]	203 [b]	222 [a]	6.2
Butterfat (%)	4.35	4.46	4.46	4.57	0.079
Protein (kg)	125 [c]	155 [b]	162 [ab]	174 [a]	4.9
Protein (%)	3.53	3.57	3.56	3.58	0.041
Live weight start of lactation (kg)	383 [b]	388 [ab]	383 [b]	409 [a]	9.4
Live weight end of lactation (kg)	416 [b]	421 [b]	425 [ab]	446 [a]	7.96
Live weight change (kg)	33	33	42	37	7.3
Condition score start of lactation	2.2 [b]	2.3 [b]	2.4 [b]	2.6 [a]	0.08
Condition score end of lactation	2.1 [b]	2.2 [b]	2.5 [a]	2.6 [a]	0.095
Intercalving period (days)	375 [a]	425 [b]	383 [ab]	416 [b]	10.8

[abc] Row means with common superscripts do not differ (P >0.05); [d] s.e.m. = Standard error of mean;
[e] FCM = 4% Fat corrected milk
[f] Concentrate level: NC = No concentrate 0 kg/cow/day, LC = Low concentrate 2.4 kg/cow/day, MC = Medium concentrate 4.8 kg/cow/day, HC = High Concentrate 7.2 kg/cow/day

Table 4 Prediction of FCM production over a 300 day lactation: $Y = a + bx^{0.5}$, x = kg concentrate/cow/day, $r^2 = 0.37$, fitted Standard Error = 742.5, F-value = 62.3

Parameter	Value	Std Error	t-value	95% Confidence limits		P>|t|
a	3742	134.3	27.9	3475	4008	0.0000
b	557	70.6	7.89	417	697	0.0000

by cows fed the low (2.4 kg), medium (4.8 kg) and high (7.2 kg) level of concentrate respectively over the two lactations. Robaina *et al*. (1998) reported that cows grazing on ryegrass/clover pasture that were fed 0, 1.8, 3.4 and 6.7 kg of concentrate per day produced 12.9, 15.7, 16.1 and 18.4 kg of milk per day with an average butterfat of 4.4%.The milk response was 1.5, 0.9 and 0.82 kg of milk/kg concentrate fed at the different concentrate levels, which is higher than that reported in our study. The genetic ability of cows to respond to concentrate feeding on a pasture based system may vary. In a study done in New Zealand it has been shown that the response to concentrate feeding was 0.63 and 0.45 kg milk per kg of concentrate for New Zealand Holsteins and 0.9 and 0.84 kg milk per kg of concentrate for North American Holsteins when fed 3 or 6 kg of concentrate per day respectively (J.R. Roche, Personal communication, e-mail: john.roche@dexcel.co.nz). Grainer & Mathews (1989) found that the response in milk yield was 0.97, 0.69 and 0.28 kg/kg DM concentrate fed at 3.2 kg/cow/day when 8, 17 and 33 kg DM of pasture was allocated per cow/day, respectively. Hoden *et al*. (1991) showed a return of 0.6 kg FCM for each kg of concentrate fed at 3.7 kg/day to high yielding dairy cows. At the higher levels of concentrate feeding the substitution rate can be expected to be high (Faverdin *et al*., 1991) resulting in a lower milk response to concentrate feeding. Concentrate feeding had no significant effect on the butterfat or protein content of milk over two lactations.

The live weight of cows at the start of lactation was higher for the HC treatment compared to cows on the other treatments. Cows on all treatments gained live weight during lactation. Live weight change from the start to the end of lactation did not differ between treatments. At the end of lactation the live weight and condition score of cows on the HC treatment was higher than that of cows on the NC and LC treatment. The cows on the NC treatment had a similar live weight at the end of lactation than cows on the NC and LC treatment. Regressions fitted to predict live weight and condition score using the level of concentrate feeding as independent variable had a R^2 of less than 0.03, indicating that concentrate feeding level did not affect liveweight and condition. At the start of lactation the condition score of cows on the HC treatment was higher than that of cows on the other treatments. The condition score of cows on the HC and MC treatment at the end of lactation was higher than that of cows on the NC and LC treatments. Cows on the HC treatment did not store too much energy as the condition score was 2.7 at the end of the second lactation. The condition score tended to improve as the level of concentrate feeding increased. It is to be expected that higher levels of concentrate feeding will result in a higher live weight and condition score in cows.

The cows fed no concentrate had a significantly shorter calving interval than cows fed at the high level of concentrate. The intercalving period (ICP) for cows on the LC, MC and HC did not differ from each other. Cows on the NC treatment had a shorter ICP than cows on the LC and HC treatment. Feeding no concentrate to cows for two lactations did not have a negative effect on the ICP of cows although the condition score was low at 2.1 to 2.2. The intercalving period may be affected by many factors such as calving ease, incidence of milk fever, heat observation, timing of insemination, insemination technique as well as nutrition of the cow. Keady *et al*. (2001) showed that concentrate supplementation in late lactation did not alter dairy cow fertility in subsequent lactations.

With the present concentrate price of R 1.60/kg, pasture cost of R 0.40 and milk price of R 1.80 the margin over feed cost was R 529, R 583, R 521 and R 519/cow/month respectively on the NC, LC, MC and HC treatments respectively. The economics of concentrate feeding should be calculated on a whole farm basis. Higher levels of concentrate feeding to cows on pasture will result in higher substitution rates and require higher stocking rates to ensure effective pasture utilization (Faverdin *et al*., 1991).

Conclusions

The feeding of concentrates did result in increased production of milk, butterfat and protein per lactation and a higher condition score. The butterfat and protein percentage of milk was not affected by the feeding of concentrates over two lactations. Concentrate feeding did not shorten the intercalving period over two lactations. Jersey cows grazing on kikuyu, annual ryegrass, lucerne and perennial ryegrass/clover pasture produced 3742 kg FCM over a 300 day lactation (12.5 kg FCM/day) with only a mineral supplement. The milk response per kg of concentrate fed was 1.25, 0.78 and 0.54 kg FCM in cows fed the low (2.4 kg), medium (4.8 kg) and high (7.2 kg) level of concentrate respectively over two lactations. The study showed a diminishing return on concentrate feeding as the level of concentrate feeding increased. The highest margin over feed cost (R 583/cow/month) was obtained at the low level of concentrate feeding (2.4 kg/cow/day).

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