Substituting maize grain with barley grain in concentrates fed to Jersey cows grazing kikuyu-ryegrass pasture

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Abstract

The aim of the study was to determine the effect of substituting maize grain with barley grain in the diet of lactating Jersey cows grazing kikuyu-ryegrass pasture. Sixty Jersey cows were blocked in terms of number of days in milk, lactation number, milk yield and live weight and randomly assigned to one of five treatments (n = 12). The five treatments consisted of concentrate mixtures (12 MJ ME per kg/dry matter (DM), 130 g crude protein (CP)/kg DM) containing maize grain and barley grain at ratios of 100:0, 75:25, 50:50, 25:75 and 0:100. The cows received 6 kg (as fed basis) of the concentrate mixture a day, 3 kg during morning milking and 3 kg during afternoon milking. The investigation was conducted over a period of 42 days (14-day adaptation and 28-day measurement period). The cows strip-grazed an irrigated kikuyu-ryegrass pasture (157 ± 17.7 g DM/kg; 202 ± 42.6 g CP/kg DM; 447 ± 40.3 g neutral detergent fibre/kg DM). Milk yields were recorded daily. Milk samples were collected weekly and analyzed for milk fat and protein content. Body condition scores and live weights were recorded at the start and end of the experimental period. Milk production four weeks prior to the experiment was used as co-variate. The cows receiving the concentrate mixture containing an equal proportion of maize and barley grain (50:50) produced significantly more milk (17.0 kg/day) than those receiving the concentrate mixtures containing pure maize grain (15.7 kg/day) or pure barley grain (14.9 kg/day). Milk fat percentage, milk fat yield, protein percentage, live weight change and body condition score were not affected when barley grain substituted maize grain in the concentrate mixture. These results suggested that barley grain could be a successful substitute for maize grain in concentrates fed to Jersey cows grazing cultivated pasture in the Southern Cape region of South Africa.

Keywords: Dairy, maize grain, barley grain, energy source, pasture-based, milk yield, milk composition
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Introduction

Economic competitiveness in the dairy industry depends heavily on proper nutritional management. Feed supply to the herd comprises 60 to 70% of the total cost of milk production (Parker, 1999). Milk production of cows on pasture-based systems is limited by the intake of metabolisable energy (ME) (Bargo *et al.*, 2003). Maize is the main energy source used in concentrates for dairy cows grazing cultivated pasture in the Southern Cape. Barley, a high-energy small grain crop is produced in the winter rainfall areas of South Africa. Depending on price, quality and availability, barley could substitute maize in dairy concentrate mixtures. The use of barley could reduce the production cost of milk and increase the profitability of milk production.

The net energy value of barley is comparable to that of maize (Kennelly *et al.*, 2000), but barley grain has to be processed to maximize its digestibility. Processed barley grain is digested more rapidly in the rumen than maize. This increases the risk of metabolic disorders which could affect overall animal productivity (Kennelly *et al.*, 2000). It is therefore imperative that the enhanced rate of fermentation of barley is taken into consideration when it is used to replace maize in concentrate mixtures fed to dairy cows (Beauchemin & Rode, 1999). Studies in which maize was replaced by barley have been reported by various authors (Friggens *et al.*, 1995; Beauchemin & Rode, 1999; Khorasani *et al.*, 2001). However, these experiments differed considerably with regard to amount of concentrate fed, type of energy source, grain processing, type and quality of pasture and feeding system used.

The aim of this investigation was to determine the effect of substituting maize with barley grain in the concentrate mixtures fed to lactating Jersey cows grazing kikuyu-ryegrass pastures in the Southern Cape.

Materials and Methods

The experiment was conducted from mid-August to end-September 2001 on the Outeniqua Experimental Farm of the Department of Agriculture, Western Cape Province, close to the city, George, situated at 33º 58′ 38″ S, 22º 25′ 16 ″E and at an altitude of 210 metres. The milk production study consisted of a 14 day adaptation period followed by a 28 day measurement (experimental) period. Sixty multiparous Jersey cows in early to mid-lactation were blocked and randomly assigned within blocks to one of five treatments. Group averages for days in milk (DIM), lactation number, milk production and live weight were similar four weeks prior to the study (Table 1). The treatments consisted of replacing 0, 25, 50, 75 or 100% of the maize in the concentrate with barley (Table 2). All concentrate mixtures were formulated to be isonitrogenous, and were pelleted. Cows were fed 6 kg of concentrate mixture per day, on an as fed basis, split into two feedings, *viz.* at the morning and at the afternoon milkings.

Table 1 Treatment group means (± standard deviation) of days in milk (DIM), lactation number, milk production (four weeks prior to study) and live weight (kg) of Jersey cows (12/treatment) at the beginning of the study

	Treatments [1] (Maize : barley ratio)				
	1 (100:0)	2 (75:25)	3 (50:50)	4 (25:75)	5 (0:100)
DIM	61 ± 29.9	55 ± 19.7	58 ± 24.8	51 ± 17.3	52 ± 18.1
Lactation no	2.9 ± 1.9	2.9 ± 1.6	3.2 ± 1.8	3.1 ± 2.2	3.0 ± 2.0
Milk production (kg/day)	15.5 ± 2.3	15.0 ± 2.1	15.7 ± 2.4	15.6 ± 2.8	15.5 ± 2.8
Live weight (kg)	337 ± 7.9	339 ± 34.2	347 ± 27.8	335 ± 30.2	343 ± 48.9

[1] Treatments: 6 kg concentrates were fed in equal amounts during the morning and afternoon milkings

The live weight (LW) and body condition score (BCS) of each cow were determined at the beginning and end of the experimental period. To calculate mean weights cows were weighed on a Tru-test Ezi weigh version 1.0 scale (0.5 kg accuracy) after the morning milking on two consecutive days. Body condition score was determined according to the five-point scale of the Mulvany (1977) method. To ensure consistency, the same person determined BCS at the beginning and end of the experiment.

Cows grazed a kikuyu pasture that had been over-sown during March (autumn) with ryegrass (*Lolium multiflorum* - cv Energa*)* at 20 kg seed/ha. The pasture consisted predominantly of ryegrass since kikuyu is dormant during August and September in the Southern Cape (Botha, 2003). Pasture was allocated at approximately 12 kg DM per cow per day to ensure that pasture intake was not limiting. Fertilizer was applied at 56 kg nitrogen (N) in the form of limestone ammonium nitrate (LAN) after each grazing.

The pasture was sampled on a weekly basis by cutting three areas of 0.1 m^2 at a height of 3 cm. Grab samples of the concentrate mixtures were collected on Mondays, Wednesdays and Fridays, and pooled for each seven days during the experimental period, resulting in four composite samples for each treatment. Samples were weighed on a Sartorius BP8100 (d = 0.1 g) scale and dried at 60 °C for 72 hours in a Labcon Economy force-draft oven to determine DM percentage. Composite dried samples of both the pasture and concentrate mixtures were milled in a Retsch GmbH5657, Type SMI 31405 laboratory mill through a 2 mm sieve, and stored at –20 °C.

During the experimental period daily milk yields were recorded at each milking, and milk samples were collected once a week during the morning and afternoon milkings. These samples were preserved with sodium dichromate, stored in containers and sent to the laboratory immediately after the morning milking for analyses of milk fat, protein content and milk urea nitrogen (MUN), using a MilkoScan FT 6000 analyzer IDF (1996). Milk yields were converted to a 4% fat corrected milk (FCM) (0.4 x kg milk) + (15 x kg butterfat) basis.

Pasture and concentrate samples of the feed offered were analyzed for DM, organic matter (OM), Ca, P and N (AOAC, 1995). The conversion factor of N x 6.25 was used to calculate crude protein (CP) (AOAC, 1995). Neutral detergent fibre (NDF) was determined by heating a 0.5 g sample to boiling point in 100 mL of neutral detergent plus 50 μL of heat stable amylase (Dietary fiber kit; Sigma catalogue Number 3306) added before heating. Sodium sulphate was not added and a sample was boiled for one hour and filtered (Van Soest *et al.*, 1991). The *in vitro* organic matter digestibility (IVOMD) was determined according to the Tilley & Terry (1963) method. The ME content was calculated according to ARC (1984) as: ME (MJ/kgDM) = 18.4 x IVOMD x 0.81.

Table 2 The ingredients and chemical composition of concentrate mixtures containing maize and barley grains in different proportions

	Treatments [1] (Maize : barley ratio)				
	100:0	75:25	50:50	25:75	0:100
Ingredients (g /kg, as fed basis)					
Maize	868	651	434	217	0
Barley	0	217	434	651	868
CSOC	90	90	90	90	90
Urea	5	3.75	2.5	1.25	0
Bran	0	1.25	2.5	3.75	5.0
DiCaP	13	13	13	13	13
Feed lime	12	12	12	12	12
Salt	5	5	5	5	5
MgO	5	5	5	5	5
Premix [2]	2	2	2	2	2
Nutrient composition (g/kg dry matter)					
Dry matter	884	887	883	892	895
Ash	84	84	88	92	89
Nitrogen	20.5	20.5	19.8	19.7	19.7
Crude protein	127.8	127.9	123.8	123.4	123.4
IVOMD	893	885	888	880	864
ME (MJ/kg)	13.3	13.2	13.2	13.1	12.9
NDF	159	241	197	228	295
Ca	8.0	8.7	9.0	9.3	8.4
P	7.1	6.9	7.3	7.6	8.0

[1] Treatments: 6 kg concentrate were fed in equal amounts during the morning and afternoon milkings
[2] Two kg premix contained: Vitamin A - 10 000 000 IU; vitamin D_3 - 1 000 000 IU; vitamin E - 20 000 IU; Mn - 1 93 g; Zn – 262 g; Fe - 100 g; Cu - 45g; I - 4 g; Se - 0.5 g; Co - 4.32 g
CSOC - cotton seed oil cake; IVOMD - *in vitro* organic matter digestibility; NDF – neutral detergent fibre;
ME - metabolisable energy (ME) (calculated)

An analysis of variance was performed on all variables using SAS (1996). Milk production four weeks prior to the experiment was used as co-variate.

Results

The kikuyu-ryegrass pasture contained (/kg DM): 118 g ash; 32 g N; 202 g CP; 13.5 MJ ME; 4 g Ca; 4 g P; 447 g NDF and had an IVOMD of 84.5%. The results of milk production, milk composition, live weight change (LWC) and BCS are presented in Table 3.

Cows fed concentrate mixtures containing more than 75% barley had lower milk, FCM and protein yields than cows fed the concentrate with a grain component consisting of 50% barley and 50% maize. Milk fat percentage, milk fat yield, protein percentage, LWC and BCS were not affected when barley substituted maize in concentrate mixtures. The MUN was significantly lower for the cows that were fed a pure maize (100:0) concentrate mixture than for those receiving a pure barley (0:100) concentrate mixture.

Table 3 Milk production, milk composition, live weight change (LWC) and BCS values obtained from Jersey cows on kikuyu/ryegrass pasture, fed 6 kg concentrate mixture per cow per day (as fed basis) with different maize : barley ratios

Parameters	Treatment [1] (maize : barley ratios)					s.e.m.
	100:0	75:25	50:50	25:75	0:100	
Milk (kg/day)	15.7 [bc]	16.3 [ab]	17.0 [a]	14.9 [bc]	14.9 [c]	0.463
FCM (kg/day)	16.9 [ab]	17.4 [ab]	17.8 [a]	15.8 [b]	15.9 [b]	0.603
MUN (mg/dL)	14.9 [b]	15.2 [ab]	15.2 [ab]	15.5 [ab]	15.8 [a]	0.307
Milk fat yield (kg)	0.72 [a]	0.71 [a]	0.73 [a]	0.67 [a]	0.66 [a]	0.032
Milk fat (%)	4.55 [a]	4.44 [a]	4.37 [a]	4.45 [a]	4.56 [a]	0.185
Protein yield (kg)	0.59 [ab]	0.59 [ab]	0.63 [a]	0.58 [b]	0.56 [b]	0.016
Protein (%)	3.76 [a]	3.71 [a]	3.72 [a]	3.92 [a]	3.85 [a]	0.856
LWC (kg)	6.43 [a]	1.38 [a]	0.49 [a]	-1.17 [a]	6.33 [a]	3.194
BCS – change (1-5)	0.20 [a]	0.04 [a]	0.09 [a]	0.13 [a]	0.12 [a]	0.077

[1] Treatment: Concentrates were fed in equal amounts during the morning and afternoon milkings
FCM – fat corrected milk; MUN - milk urea nitrogen; BCS - body condition score measured on a scale of 1 – 5
[a b c] Means within a row without common superscripts differ ($P < 0.05$); s.e.m. – standard error of mean

Discussion

Cows fed concentrate mixtures with equal proportions of maize and barley (50:50) produced significantly more milk than cows fed the concentrate mixture with maize as the only grain component. The combination of maize (slow fermentation rate) and barley (rapid fermentation rate) may have resulted in a more even fermentation rate that enhanced more effective energy release (Henning, 1987) and increased production. This interaction is referred to as the associative effects among feeding ingredients (Dixon & Stockdale, 1999). Overton *et al*. (1995) evaluated the effect of feeding different mixtures of maize and barley on the productivity of dairy cows. In their study milk production and 4% FCM were highest for cows fed diets containing maize and barley in the ratio of 75:25. They concluded that a higher DMI could have contributed to the increased milk production.

When the barley level was increased to 75% of the concentrate mixture in the present study, milk production, FCM and protein yield decreased, probably due to a too rapid rate of starch digestion from the high ratio of barley. This could lead to digestive disorders and affect overall production (Kennely *et al.*, 2000).

Neither milk fat percentage nor milk fat yield was affected when barley replaced maize. Khorasani *et al.* (2001) also found that milk fat was not affected when maize replaced barley in an experiment to determine the effect of the grain source on animal performance. Harris (1996) observed that protein percentage was unchanged when mixtures with different maize to barley ratios were fed, and that the milk protein concentration remained above 3.2%, indicating that the protein and the carbohydrate ratio were balanced (Harris, 1996). Contrary to the results of this experiment, Smith *et al*. (1994) found that pure maize concentrate mixtures resulted in higher milk fat percentages than pure barley concentrate mixtures. Overton *et al.* (1995), on the other hand, reported an increase in the milk production with concentrate mixtures containing 75% maize grain and 25% barley grain when compared to pure maize grain (100:0) concentrate mixtures. The results of studies comparing grain sources are inconsistent due to intricate interrelations among several factors, such as composition of the grain, amount of feed consumed per unit time, mechanical alterations, chemical alterations and the degree of rumen microbial adaptation to the diet, etc.

Milk urea nitrogen was significantly lower for those cows that were fed the pure maize grain (100:0) concentrate mixture compared to those receiving the pure barley (0:100) concentrate mixture. However, this was still within the optimum levels of 14.9 to 15.5 mg/dL for dairy cattle on pasture (Chase, 1997). Various factors could influence MUN and a MUN value should not be evaluated in isolation when data are interpreted (Jonker *et al*., 2002).

There were no differences in the LWC or BCS in any of the treatment groups. Numerous factors that could influence live weight changes, and results over a short time are not always reliable (Komaragiri & Erdman, 1996) and should be interpreted with caution. Body condition score changes are even more difficult to interpret in studies of short duration.

Conclusion

Milk production increased when barley grain substituted 50% of the maize grain in concentrate mixtures for dairy cows grazing kikuyu-ryegrass pasture. Combinations of maize grain and barley grain could be included in concentrate mixtures to gain the benefit of associative effects, resulting in increased production.

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