Feed intake and production parameters of lactating crossbred cows fed maize-based diets of stover, silage or quality protein silage

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Abstract Thirty-six Boran × Friesian dairy cows (392 ± 12 kg; mean $\pm$ SD) in early parity were used in a randomised complete block design. Cows were blocked by parity into three blocks of 12 animals and offered normal maize (NM) stover (T1), NM silage (T2) or quality protein maize (QPM) silage (T3) basal diets supplemented with a similar concentrate mix. Feed intake, body weight and condition changes and milk yield and composition were assessed. The daily intake of DM, OM, NDF and ADF for cows fed the NM stover-based diet was higher ($P < 0.05$) than for the cows fed the NM silage and QPM silage-based diets. However, the daily intake of DOM (9.3 kg) and ME (140.8 MJ) for cows on QPM silage-based diet was higher ($P < 0.05$) than for cows on NM stover-based diet (8.4 kg and 124.2 MJ) and NM silage-based diet (7.9 kg and 119.1 MJ). Body weight of cows was affected ($P < 0.05$) by the diet, but diet had no effect ($P > 0.05$) on body condition score, milk yield and milk composition. The digestible organic matter in the NM stover-based diet (724 g/kg DM) was lower ($P < 0.05$) than that in the NM (770 g/kg DM) and QPM silage-based diet (762 g/kg DM). It was concluded that the performances of the cows on the NM silage and QPM silage diets were similar and were not superior to that of the NM stover-based diet.

Keywords Body condition score · Body weight change · Feed intake · Production parameter · Quality protein maize silage · Normal maize stover

Abbreviations

ADF	Acid detergent fibre
CP	Crude protein
DM	Dry matter
DOM	Digestible organic matter
NDF	Neutral detergent fibre
NM	Normal maize
QPM	Quality protein maize

Introduction

The major constraint to cattle production in Ethiopia is nutrition. Cattle are predominantly fed on natural pastures and crop residues. However, due to rising human population, traditional grazing lands are widely being converted to croplands, forcing cattle to graze on marginal and overgrazed lands with poor quality forage (Kitaba and Tamir 2007).

Maize is a major source of food for millions of poor Africans. According to CIMMYT (2000), three systems of maize utilisation as food/feed can be envisaged. First, harvesting the crop at grain maturity and using the grain for human consumption while the stover is used as livestock feed—this is the most common use of maize in developing countries; second, harvesting the plant at the dent stage, marketing the ears for human consumption and using the greener forage as feed; third, harvesting the whole plant at the dent stage and using it as livestock feed. The two latter

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options require a system of conserving the relatively higher quality forages.

Conserved feeds such as silages are an integral part of dairy cattle diet in intensively managed peri-urban dairy farms, although the availability of maize silage to such dairy farms has not been well documented. In Ethiopia, a new variety of maize referred to as “Quality Protein Maize” (QPM) is being promoted for adoption by smallholder farmers to improve agricultural production and ensuring food security (CIMMYT 2000). It is generally believed that QPM is superior to normal maize (NM) variety in terms of nutrient content and animal performance. This study tested the hypothesis that feeding QPM silage-based diet would result in superior performance in lactating crossbred dairy cows. Results were compared with stover- and silage-based diets from the traditional NM variety.

Materials and methods

Study site and animals

The study was carried out at the International Livestock Research Institute (ILRI), Debre Zeit Research Station in Ethiopia. The station is located at 38°58' E and 8°44' N at an elevation of 1,850 m above sea level. The mean annual rainfall and temperature during the study were 860 mm and 18°C, respectively. The minimum and maximum temperatures in the barn were 16°C and 29°C with a mean temperature of 23°C.

Thirty-six crossbred Boran (*Bos indicus*) × Friesian (*Bos taurus*) cows (50–75% Friesian) in early lactation and 1–3 parities were used. Mean initial body weight of the cows was 392 ± 12 kg (mean ± SD). The cows were de-wormed against internal parasites and sprayed against ecto-parasites prior to the beginning of the experiment.

Feeds, treatments and experimental design

Two maize varieties viz., NM and QPM were grown at ILRI Debre Zeit Research Station. The maize varieties were harvested at the dent stage and ensiled with average DM contents of 29% for NM and 31% for QPM, respectively, with no additives used for ensiling. Also, the stover of the NM variety was collected and stored for later use. The silages and stover constituted the basal diets, which were supplemented with similar concentrate mix. Treatments consisted of feeding the NM stover-based diet +8 kg/day concentrate mix (T1), NM silage-based diet +8 kg/day concentrate mix (T2), and QPM silage-based diet +8 kg/day concentrate mix (T3). The cows in T1 were supplemented with 440 g/day of maize grain to compensate for the grains present in the maize cobs of silages in the basal diets of T2 and T3. The diets were formulated to contain a CP

content of 10% in order to meet the CP requirement of a lactating cow producing 11 kg of milk.

Cows were fed individually and had free access to clean drinking water and mineral licks. They were adapted to their respective diets for 4 weeks prior to the expected dates of calving and continued on the same diet after calving.

The basal feeds were offered ad libitum whereas concentrate supplements were offered daily in two equal meals at 0830 and 1400 hours in separate troughs. Orts were collected and weighed daily between 0800 and 0830 hours the next day, before offering fresh feeds. The amount of the basal diets offered was adjusted to maintain 5% Orts during the feeding trial of 90 days. The experiment was conducted in randomised complete block design with three treatments. The cows were blocked by parity into three groups, and four animals from each parity group were randomly assigned to one of the three treatments making 12 animals per treatment.

Feed intake, body weight change and milk yield and composition

The daily feed intake on a DM basis was determined by the difference between feed offered and Orts. Initial body weight of the cows was recorded on the first day of the experiment and thereafter the body weight and body condition score of cows were taken at 2-week intervals after overnight fasting. Body condition score of cows was recorded by visual observation and manual assessment to score the dairy cows on a 1 to 9 scale (where 1 = emaciated, 9 = fat) combining the procedures of Nicholson and Butterworth (1986) and Edmington et al. (1989) developed for Zebu (*B. indicus*) breeds of cattle and Holstein dairy cows, respectively.

The daily body weight gain of each cow was calculated as the difference between the initial body weight and final body weight divided by number of experimental days. Efficiency of feed utilisation was determined by dividing the daily DMI by 4% FCM (fat corrected milk) yield of each animal (NRC 2001).

The cows were hand milked twice a day at 0600 and at 1600 hours, starting the 7th day post-calving. Fat corrected milk (4% FCM) yield was calculated according to NRC (2001). Milk samples were collected on 30, 60 and 90 days of lactation for seven consecutive days for analysis.

Faeces collection

At the end of the feeding trial, five randomly selected cows from each treatment were used in a digestibility trial. Cows were adapted to carry faecal collection bags for 3 days, which was followed by total faeces collection for seven successive days. Total faeces was collected and weighed every morning before feeding and 5% of the faeces was sub-sampled, placed in airtight plastic bags and stored in a

Table 1 Ingredient proportion (%) of experimental diets (DM basis) of cows fed either NM stover, NM silage or QPM silage-based diets

Ingredient proportion (%)	Treatment		
	NM stover-based diet	NM silage-based diet	QPM silage-based diet
NM stover	45.4	0.0	0.0
NM silage	0.0	41.3	0.0
QPM silage	0.0	00	42.4
Ground maize grain	2.85	0.0	0.0
Wheat bran	46.6	52.8	51.78
Molasses	3.22	3.68	3.61
Bone meal	1.28	1.48	1.46
Salt	0.65	0.74	0.75

NM normal maize, QPM quality protein maize

deep freezer at -20°C . On the last day of the collection period, samples were thawed and thoroughly mixed for each animal to determine DM, N, NDF and ADF. The same feeding levels were used as described in the feeding phase.

Chemical analysis

Feed and faecal samples were dried at 60°C for 48 h to constant weight in a forced draught oven and then ground to pass through 1 mm sieve. The DM, OM and ash in feed and faecal samples were analysed according to AOAC (1980) and NDF, ADF, ADL and ADF-ash according to Goering and Van Soest (1970). Metabolisable energy (ME, MJ/kg DM) was estimated as $\text{ME} = 0.19 \times \text{DOMD}\%$ (MAFF 1984), where DOMD is digestible OM in the DM.

Milk protein was analysed using formaldehyde titration ($6.38 \times \text{N}$) as suggested by Scott (1986). The milk fat content was determined using the Gerber method with BS 696 and milk total solids with BS 1741 (British Standard Institute 1989). Lactose content of the milk was determined as the $[\text{DM} - (\text{protein} + \text{fat} + \text{ash})]$.

Data analysis

Data were analysed using the general linear model of the Statistical Analysis System (SAS 2002). Duncan's multiple range test was used to separate treatment means. The

response variables were analysed using the statistical model: $Y_{ijk} = \mu + P_i + \alpha_j + \beta(x_{ijk} - \bar{X}) + \epsilon_{ijk}$, where, Y_{ijk} = dependent variable, μ = overall mean, P_i = the i th parity effect (block), α_j = the j th treatment effect, β = the true common slope of the regression line, $\bar{X}$ = The overall mean of the covariate, ϵ_{ijk} = random effect. The initial milk yield was introduced into the model as a covariate.

Results

Ingredient proportion and chemical composition feeds

Ingredients used in the formulation of experimental diets for lactating cows are presented in Table 1. The treatment diets had similar ingredients, except the ground maize grain included in NM stover-based diet to compensate for maize grains present in NM and QPM silages. The mean chemical composition of the three maize varieties, concentrate mix and supplementary maize grain (Table 2) indicated that the CP content of the NM and QPM silages were similar and both were higher than the NM stover.

The NM and QPM silage-based diets had similar contents of DM, OM, NDF and ADF (Table 3). The DM content of the NM stover-based diet was higher than those of the NM and QPM silage-based diets. The NM stover-based diet had the

Table 2 Mean chemical composition of basal feeds, concentrate and maize grain used in feeding of lactating cows

Chemical composition	Feeds used for the experiment				
	NM stover	NM silage	QPM silage	Concentrate	Maize grain
DM (g/kg)	918	882	881	879	884
OM (g/kg DM)	875	914	919	921	980
Total ash (g/kg DM)	125	91	81	6.5	2
CP (g/kg DM)	52.3	76.6	73.6	147	93
NDF (g/kg DM)	696	588	574	338	175
ADF (g/kg DM)	462	366	371	120	61
ADL (g/kg DM)	49	49.3	43.1	22.8	6.4

ADF acid detergent fibre, ADL acid detergent lignin, CP crude protein, DM dry matter, NDF neutral detergent fibre, NM normal maize, OM organic matter, P phosphorus, QPM quality protein maize

Table 3 Nutrient composition of experimental diets (DM basis) of cows fed NM stover, or NM silage or QPM silage-based diets

Nutrient content	Treatment		
	NM stover-based diet	NM silage-based diet	QPM silage-based diet
DM (g/kg)	897	880	880
OM (g/kg DM)	875	910	919
DOM (g/kg DM)	630	701	698
Total ash (g/kg DM)	125	90	81
CP (g/kg DM)	102	118	116
NDF (g/kg DM)	518	466	463
ADF (g/kg DM)	273	223	224
ADL (g/kg DM)	49	49	43
ADF-ash	44.6	33.7	38
ME (MJ/kg DM)	7.5	9.0	8.7

ADF acid detergent fibre, ADL acid detergent lignin, CP crude protein, DM dry matter, ME metabolizable energy, MJ mega joule, NDF neutral detergent fibre, NM normal maize, OM organic matter, QPM quality protein maize

lowest OM followed by the NM and QPM silage-based diets. The digestible organic matter (DOM) and ME contents in the NM silage and QPM silage-based diets were higher than the values in the NM stover-based diet, but they were similar among silage-based diets. The NM stover-based diet had higher NDF, ADF and ADF-ash than the silage-based diets, whereas the NDF and ADF in silage-based diets were similar. The NM silage-based diet had slightly higher ADF-ash than the QPM silage-based diet. Total ash was higher in NM stover than the two silages.

Nutrients intake and digestibility and production parameters

Mean DMI and OMI were higher ($P<0.01$) for cows fed the NM stover-based diet than for the NM and QPM silage-based diets (Table 4). The daily crude protein intake was similar among dietary treatments. The DOM intake (DOMI) was higher ($P<0.05$) for cows fed the QPM silage-based diet than cows fed NM silage-based diet, but the difference

between the NM stover-based and NM silage-based diets was not significant ($P>0.05$). The digestibility of DM, OM, CP and NDF was not affected ($P>0.05$) by dietary treatments (Table 5).

The mean body weight loss of dairy cows during the trial was highest ($P<0.05$) for cows fed the NM silage-based diet and lowest for cows fed NM stover-based diet (Table 4). There was no significant ($P>0.05$) change in body condition score of the cows. Milk yield, 4% FCM yield and milk composition of cows were not affected ($P>0.05$) by dietary treatments (Table 6).

Discussion

Chemical composition of the feeds

The NM stover had low CP and high fibre fractions, characteristics consistent for most cereal crop residues. The

Table 4 Daily feed DM and nutrients intake, and body weight change and body condition score of cows fed NM stover, or NM silage or QPM silage-based diets

	Treatment			SEM
	NM stover-based diet	NM silage-based diet	QPM silage-based diet	
Intake				
DM, kg/day	12.6 ^a	11.1 ^b	11.3 ^b	0.25
OM, kg/day	11.4 ^a	10.3 ^b	10.5 ^b	0.22
NDF, kg/day	6.7 ^a	5.1 ^b	5.1 ^b	0.15
ADF, kg/day	4.3 ^a	3.3 ^b	3.4 ^b	0.12
CP, kg/day	1.28	1.31	1.31	0.017
DOM (kg/day)	8.4 ^{ab}	7.9 ^b	9.3 ^a	0.42
ME (MJ/day)	124.2 ^{ab}	119.1 ^b	140.8 ^a	0.06
Body weight and condition score				
BW change, g/day	-102 ^a	-217 ^c	-129 ^b	12.6
Initial BCS	4.8	5.0	4.6	0.19
Final BCS	4.3	4.5	4.6	0.17
EFU	1.0	0.9	0.9	0.19

Means with different superscript letters in a row are significantly different at $P<0.05$

ADF acid detergent fibre, BCS body condition score, BW body weight, CP crude protein, DM dry matter, DOM digestible organic matter, EFU efficiency of feed utilisation, ME metabolizable energy, NDF neutral detergent fibre, NM normal maize, OM organic matter, QPM quality protein maize, SEM standard error of means

Table 5 Apparent digestibility coefficient of feed nutrients in cows fed NM stover or NM silage or QPM silage-based diets

Digestibility coefficient	Treatment			SEM
	NM stover-based diet	NM silage-based diet	QPM silage-based diet	
DM	0.70	0.75	0.74	0.026
OM	0.72	0.77	0.76	0.025
CP	0.74	0.76	0.75	0.021
NDF	0.69	0.70	0.69	0.020

CP crude protein, DM dry matter, OM organic matter, NDF neutral detergent fibre, NM normal maize, QPM quality protein maize, SEM standard error of means

CP content of the NM and QPM silages in the present study was within the range of the minimum level of 7.5% required for optimum rumen function (Van Soest 1994). However, the CP content of the NM stover below the minimum CP level required. The low CP contents of maize varieties in the present study reflected the need for protein supplementation in stover- and silage-based diets. The higher energy content of the NM and QPM silage-based diets might be due to the effect of ensiling, because it increases the energy content of the feeds (De Visser 1993).

Intake and digestibility of nutrients

The higher DMI of the NM stover-based diet than the NM silage-based diet was consistent with the reports that silage DMI was lower than intakes of fresh or dried forages from similar material (Fitzgerald and Murphy 1999). The lower DOMD, DOMI and ME content of the NM stover-based diet than the silage-based diets could be explained, at least in part, by its chemical composition, since NM stover-based diet exhibited very low OM content compared to NM and QPM silage-based diets. The low CP intake by cows fed the

NM stover diet and the higher CP intake by cows fed the NM and QPM silage-based diets were due to the low CP concentration in the NM stover-based diet and high CP value of the NM and QPM silage-based diets.

Body weight and condition changes and milk yield and composition

The relatively high milk fat content of cows on all diets may explain the loss in body weight; however, none of the groups underwent significant body condition change, indicating the cows carried adequate fat stores and that this did not change during the experiment. The loss in body weight of cows could be attributed to suppressed feed intake in the early stages of lactation, high milk yield and milk fat content and nutritional status of cows (Grant et al. 1990).

Although milk yield and milk composition of cows in the present study were not affected by dietary treatments, Sutton et al. (1996) reported an increased milk protein content as a consequence of increased CP concentration in the diet. Depression in milk fat percent is associated with increased supply of glycolytic precursors in the form of

Table 6 Milk yield and constituents of cows fed NM stover, or NM silage or QPM silage-based diets

	Treatment			SEM
	NM stover-based diet	NM silage-based diet	QPM silage-based diet	
Yield of milk and constituents, kg/day				
Milk yield	10.9	11.2	11.2	0.38
4% FCM yield	12.2	12.7	12.7	0.37
Fat	0.52	0.55	0.55	0.014
Protein	0.33	0.37	0.35	0.005
Lactose	0.38	0.47	0.44	0.002
Milk composition, %				
Fat	4.8	4.9	4.9	0.03
Protein	3.1	3.3	3.2	1.41
Lactose	3.5	4.2	3.9	0.63
Ash	0.8	0.8	0.8	0.07
Total solids (TS)	12.2	13.2	12.8	0.21
Solids not fat (SNF)	7.4	8.3	7.9	0.85

FCM fat corrected milk, NM normal maize, QPM quality protein maize, SEM standard error of means

propionic acid or starch in the duodenum and decreased supply of lipogenic precursors, namely acetic and butyric acids (Casse et al. 1993).

Conclusions

The feeding and digestion trials did not reaffirm the assumption that QPM silage-based diet would result in a superior performance in lactating Boran x Friesian cows than the NM silage-based or NM stover-based diets. The performance among diets was similar as there was no significant difference in milk yield and composition; in fact, body weight loss in the NM stover-based diet was less than the two silage-based diets.

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