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Effect of supplementing napier grass (*Pennisetum purpureum*) with sunflower meal or poultry litter-based concentrates on feed intake, live-weight changes and economics of milk production in Friesian cows

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Abstract

A study was conducted using a randomized complete block design to determine feed intake, live-weight changes, milk yield and cost of milk production in Friesian cows fed napier grass (NG) at 10 weeks (MNG) or 15 weeks (ONG) of maturity. The MNG or ONG was supplemented with equal amounts of sunflower (SFBC) or poultry litter (PLBC) based concentrates in experiment 1, while in experiment 2, the MNG was supplemented with graded levels of the PLBC. In experiment 1, the intakes of total organic matter (TOMI) was lower (135.9 vs. 137.7 g kg $W^{0.75}$) while intake of total crude protein (TCPI) was greater (16.6 vs. 12.0 g kg $W^{0.75}$) for MNG than ONG diets ($P < 0.001$). The TOMI (137.8 vs. 135.8 $W^{0.75}$) and TCPI (14.3 vs. 14.2 $W^{0.75}$) were higher for SFBC than PLBC diets ($P < 0.05$). The yield of milk corrected for butter fat (FCM) was higher (11.0 vs. 5.7 kg cow^{-1} day^{-1}) for MNG than ONG diets ($P < 0.001$). In experiment 2, the TOMI (112.8 vs. 130.6 g kg $W^{0.75}$) and the TCPI (12.2 vs. 16.1 g kg $W^{0.75}$) were lower for MNG only diet than the mean of the supplemented MNG ($P < 0.001$). The MNG only diet supported lower yields of FCM (7.7 vs. 10.7 kg cow^{-1} day^{-1}) than the mean of the supplemented MNG ($P < 0.001$). Although supplemented cows fed MNG diets gained weight, those fed supplemented ONG diets or MNG only diet lost weight. Feeding of supplemented ONG resulted in loss of revenue while supplementing with PLBC had higher profits than SFBC. We concluded that use of the PLBC would lower costs and improve milk production in dairy cows fed NG-based diets.

Keywords: Napier; Sunflower meal; Poultry litter; Dairy cattle feeding and nutrition; Live-weight; Milk; Economics

1. Introduction

In Kenya, napier grass (*Pennisetum purpureum*) is among the major feed resources for dairy cows in the medium and high rainfall areas. The official recommendation (MoLD, 1991) is to feed napier grass (NG) at a height of 60–100 cm. Feeding NG at these stages of maturity is possible during the wet seasons when there is adequate growth. Alternatively, dairy

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farmers could opt to use other feeds during the wet seasons and thus use NG at an advanced stage of maturity during the dry seasons. However, at advanced maturity forages are characterized by high cell wall content, low N content, low digestibility, and low intake resulting in low performance by ruminants (Van Soest, 1982).

Since feeding a NG only diet at the recommended stage of maturity does not support high animal performance, supplemention with either concentrates (Anindo and Potter, 1986; Muinga et al., 1993) or fodder trees (Muinga et al., 1995) resulted in improved milk yield in dairy cows. However, commercial concentrates are too expensive for the smallholder and because of establishment and persistency related problems, the existing fodder trees are not adequate for supplementing livestock at the farm level (Mwangi, 1995). Consequently, farmers are using alternative sources of protein such as poultry litter (i.e. poultry excreta contaminated with bedding materials). Poultry litter (PL) is readily available and inexpensive as compared to the other conventional sources of protein, like cotton seed cake and sunflower cake.

Considerable data on use of poultry litter (PL) for beef production exist (McCann and Martin, 1997; Jordan et al., 1997). There is scarce information on milk yield when dairy cows fed forages other than NG are supplemented with PL based concentrates (Kayongo and Irungu, 1986; Odhuba, 1989). However, data on milk yield in high yielding cows fed NG and supplemented with PL based concentrate is however non-existent. Farmers need to know how to make inexpensive home-made concentrates using PL as a protein source and the advantages of feeding such concentrates in terms of milk yield and cost of milk production by dairy cows during the wet and dry seasons.

The objectives of this study were to determine the effects of feeding medium (MNG) or old (ONG) stage of maturity NG and supplemented with either sunflower meal (SFBC) or PL (PLBC) based concentrate on feed intake, live-weight changes, milk yield and composition, and costs of milk production in dairy cows. The effects of feeding dairy cows on the MNG supplemented with graded levels of the PLBC on the study parameters were also investigated.

2. Materials and methods

This study was conducted at the National Animal Husbandry Research Station (0° S; 36° E, altitude, 1940 m), Naivasha, Kenya. Average annual rainfall of 630 mm falls mainly from March–June and October–December for the long and short rains, respectively. Average temperature is 18°C and the soils are of moderate fertility and slightly to moderately alkaline (Jaetzold and Schmidt, 1983).

2.1. Experiment 1

Thirty two multiparous (two to four lactations), Dutch Friesian cows (live-weight 438.8±38.8 kg) were selected from a large herd at the research station based on their live-weight, milk yield and body condition. The animals previously grazed mixed pastures of Kikuyu grass (*Pennisetum clandestinum*), rhodes grass (*Chloris gayana*) and Kenya white clover (*Trifolium semipilosum*). At the beginning of the trial the cows were drenched to control internal parasites and sprayed weekly with acaricide to control ticks. The cows were blocked into two equal groups based on stage of lactation; early (45; S.D., 10 days) and mid (102; S.D., 11 days) lactations. The cows in each block were divided into four similar groups based on live-weight and number of lactation. The four groups of 4 cows each were randomly allocated to the four treatment combinations, namely; the MNG (age,10 weeks; height, 1.3 m) supplemented daily with the SFBC or the PLBC, and the ONG (age, 15 weeks; height, 2.0 m) supplemented with either the SFBC or the PLBC. The chemical composition of these feeds is presented in Table 1.

The NG was managed as recommended (MoLD, 1991) and the required amounts were estimated from intake of DM by a 450 kg cow (MAFF, 1984) and yields at respective stages of maturity (Muia et al., 1999). The field with MNG was subdivided into 70 equal plots and that with ONG into 105 equal plots. To ensure that same quality of NG was fed, clearing cuts were planned and executed sequentially starting on the plots with grass to be fed first and ending on plots with grass to be fed last (Kariuki, 1998). Clearing cuts on the plots with NG to be fed last were therefore done 70 days after the first clearing

Table 1
Mean (±S.D.) chemical composition and estimated metabolisable energy content of napier grass and concentrates used in experiments 1 and 2[a]

	Experiment 1								Experiment 2			
	MNG		ONG		SFBC		PLBC		MNG		PLBC	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Observations (*n*)	12		12		12		12		12		12	
Dry matter (g kg^{-1})	183.1	13.2	237.8	15.2	907.9	6.9	911.4	5.6	179.2	9.9	914.6	10.8
Chemical composition (g kg^{-1} DM)												
Organic matter	786.9	17.2	876.5	13.2	936.9	7.5	907.9	14.7	790.0	22.0	906.8	9.9
Crude protein	84.1	14.0	53.0	8.4	152.6	8.2	150.0	13.2	85.3	9.0	150.0	7.3
Neutral detergent fibre	544.5	20.6	630.3	19.7	234.4	20.2	249.7	21.3	540.0	20.1	250.7	20.8
Acid detergent fibre	308.8	30.8	358.2	20.4	115.5	12.4	143.9	22.1	307.3	13.7	145.1	20.6
Acid detergent lignin	39.1	7.9	51.9	6.5	37.4	4.6	48.8	10.2	39.9	7.4	47.2	7.7
Crude fat	35.3	5.1	27.1	5.6	64.3	8.3	20.1	4.5	34.6	4.9	22.4	6.1
Energy content (MJ kg^{-1} DM):												
Gross energy (GE)	16.1	1.7	16.8	1.5	19.2	1.6	17.8	1.8	15.8	2.0	17.4	1.9
Estimated ME	8.3	–	7.3	–	10.5	–	10.5	–	8.3	–	10.5	–
Estimated TPDI (g kg^{-1} DM)	79.1	–	49.0	–	114.5	–	95.7	–	117.6	–	121.3	–

[a] MNG, napier at medium maturity (age: 10 weeks; height: 1.3 m); ONG napier at old maturity (age: 15 weeks; height: 2.0 m); SFBC, sunflower meal-based concentrate; PLBC, poultry litter-based concentrate; S.D., standard deviation; ME, metabolisable energy; TPDI, total protein digested in the intestines.

cut for the MNG while for the ONG, last clearing cut was done 105 days later.

The PL, collected from a deep litter system where layers were kept for 12 months, was sun-dried for 3 days, sieved and stored in bags. The PLBC was compounded using 360, 400, 230 and 10 g kg^{-1} DM of maize germ, PL, sunflower meal (SFM) and mineral premix, respectively, while the SFBC was compounded using 630, 360 and 10 g kg^{-1} DM of maize germ, SFM and the mineral premix, respectively. The chemical composition of SFM was 931.3, 954.8, 240.8, 314.0 g kg^{-1} DM and 10.7 MJ kg^{-1} DM, while PL contained 900.2, 772.0, 164.8, 439.4 g kg^{-1} DM and 9.6 MJ kg^{-1} M of DM, OM, CP, NDF contents and estimated ME, respectively. Maize germ contained 920.2, 990.3, 90.8 and 283.7 g kg^{-1} DM of DM, OM, CP and NDF contents, respectively. Mineral premix contained 270.0, 185.1, 110.0, 30.0, 5.0, 1.6, 4.0, 4.0, 5.0, 0.2, 0.015, 0.002 g kg^{-1} DM and 1.68:1 ratio of NaCl, Ca, P, Mg, Fe, Cu, Mn, S, Zn, Co, Se, Mo, and Ca:P ratio, respectively (ARC, 1984). The concentrates were formulated to be iso-nitrogenous (24 g N kg^{-1} DM) and with a calorific value of 17.0–19.0 MJ kg^{-1} DM. The grass was chopped using an electric chaff-cutter to a mean particle length of 2.5 cm to avoid selection of the more nutritious leaves and clean water was available all the time. Feeding was done twice (08:00 and 17:00 h) daily at ad libitum level of intake (120% of previous days determined intake) and the SFBC or PLBC were offered at a daily rate of 3.65 kg DM in equal amounts during milking (06:00 and 15:00 h).

The cows were fed the diets for a 14-day adaptation, a 14-day covariance, and a 84-day experiment periods. The feeds offered and refusals were recorded for each cow daily. Representative samples of feeds offered and refusals by each cow were dried at 70°C for 24 h, bulked on a weekly basis and stored in tightly closed containers awaiting laboratory analyses. Representative samples of the concentrates were also taken weekly. Feed intake was estimated as the difference of feed offered and that refused per week. Live-weight changes were monitored fortnightly and milk samples taken twice weekly were stored at −20°C pending laboratory analyses.

2.2. Experiment 2

Forty eight cows from the same herd (live-weight 436.0±36.3 kg) were selected based on live-weight, milk yield and body condition. The cows were in their early- to mid-lactation (mean 99.3±35.9 days). Prior to the experiment, the animals were grazed on mixed pastures as described in experiment 1. The cows were blocked into two groups based on number of lactations; 16 cows in first lactation and 32 cows with two to five lactations. Each group was sub-divided based on live-weight and days in milk into four similar groups of four cows for the first lactation and eight cows for those in later lactations. The treatments were MNG only diet (T0) or MNG supplemented daily with 0.91 (T1), 3.65 (T2) or 6.35 (T3) kg^{-1} DM of the PLBC. The treatments were randomly allocated to the four sub-groups within each group. The management of the grass and other protocols were as in experiment 1.

2.3. Estimation of energy content and total protein digested in the intestines

Gross energy (GE) was determined by a bomb calorimeter (adiabatic; Gallencamp, England). The digestible OM (DOM, g kg^{-1} DM) and metabolisable energy (ME, MJ kg^{-1} DM) of NG were estimated using the equations, DOM = 677.99 − (12.57 × Age of NG in weeks) (Muia et al., 2000a). ME = DOM/1000 × 18.5 × 0.81 (AAC, 1990). The OM digestibility (OMD) and ME of the concentrates were estimated using the equations, OMD (g kg^{-1}) = 919 − (0.355NDF) + (0.387ADF) − (2.17ADL) − (0.39EE) (Jarrige, 1989). Where, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, and EE = crude fat, all in g kg^{-1} DM. DOMD (g kg^{-1} DM) = (0.92OMD) − 12 (MAFF, 1984). ME (MJ kg^{-1} DM) = DOMD × 0.015 (MAFF, 1984). The total protein digested in the intestines for NG and the concentrates were estimated in a separate study by Muia et al. (2000b).

2.4. Gross margin calculations

The cows were assumed to be under a zero-grazing system of production. The costs of milk production were estimated using the assumptions that: $y = 0.013 + (0.361x)$ (Muia et al., 1999), where, y = DM yield (ton^{-1} ha^{-1}) and x = NG age in weeks. The carrying capacity (CC) was calculated using the equation; CC = DM yield (kg ha^{-1} day^{-1})/ANDMI, where ANDMI = napier DM intake with an allowance of 25% feed left-overs. Labour requirement was one worker per every two cows at monthly earnings of Ksh. 3000.00 and 5000.00 for the rural and urban worker, respectively. The number of cuts for the MNG and the ONG were 5.2 and 3.5 per year, respectively. Fertilizer N:P:K (20:10:10) was applied at a rate of 500 kg ha^{-1} $year^{-1}$ and the cost per kg was Ksh. 26.00. The fertilizer CAN (26% N) was applied at a rate 50 kg per cut and the cost was Ksh. 20.00 per kg. The veterinary costs of Ksh. 500 cow^{-1} $month^{-1}$ included curative drugs, vaccinations, acaricide, pye grease, mastrite and bactergents (Waithaka and Nijssen, 1992).

The cost of the SFBC was Ksh. 18.00 per kg while those of the PLBC were Ksh. 12.40 and 14.40 for the rural and peri-urban areas, respectively. Majority of dairy farmers also practice commercial poultry production and supplement their animals with PL as a source of protein. Although there is yet no formal marketing, those farmers with more animals or with less PL purchase extra requirements from their neighbours. The current average price per kg of milk of Ksh. 15.00 and 25.00 were used for the rural and peri-urban areas, respectively. The milk yield, feed intake, and level of supplementation were as in experiments 1 and 2. The milk yield not corrected for butter fat content was used in calculations. The miscellaneous costs were estimated as 5% of the total costs and the currency exchange rate was Ksh. 75.00 per US dollar ($).

2.5. Laboratory analyses

Feed samples were dried at 105°C for 24 h to determine DM and ashed at 500°C for 6 h to determine ash content. The EE content was determined using the Soxhlet extraction in a diethyl ether after HCl hydrolysis and the CP content was determined using the micro-Kjeldahl procedure (AOAC, 1990). The NDF, ADF and ADL were determined according to Van Soest and Robertson (1985). Milk samples were analyzed for butter fat content (BF) using the Gerber method and the CP and solid-not-fat (SNF) contents were analyzed using the methods of Pearson (1976).

2.6. Statistical analyses

In experiment 1, analysis of variance to determine effect of treatments on study parameters (nutrient intake, live-weight changes, and milk yields and composition) was done according to a randomized complete block design in a 2×2 factorial (i.e. age of NG and supplements) arrangement. The statistical model was $Y_{ijkl} = \mu + A_i + S_j + AS_{ij} + B_k + C_l + e_{ijkl}$, where Y, dependent variable; μ, overall mean; A, age of napier effect; S, supplement effect; AS, interaction of A and S effect; B, stage of lactation; C, covariant effect; and e, the error-term. Pre-planned contrasts on the study parameters were MNG vs. ONG, SFBC vs. PLBC and early- vs. mid-lactations. In experiment 2, the effect of supplementation of the MNG with graded levels of the PLBC on the same study parameters were determined in a randomized complete block design. The statistical model was $Y_{ijk} = \mu + T_i + B_j + C_k + e_{ijk}$, where T, treatment effect and B, number of lactation effect while the other abbreviations were as described for experiment 1. The responses (linear, quadratic or cubic) of study parameters with increase in level of supplementation were also investigated. The statistical analyses and separation of means were done using the general linear model procedure in the SAS (1988) program.

3. Results

3.1. Nutritive value

The chemical composition, estimated energy and total protein digested in small intestines (TPDI) are presented in Table 1. The nutritive values of MNG or PLBC in experiments 1 and 2 were similar. The contents of CP, ME and the TPDI in ONG were lower than in MNG by 37, 12 and 38%, respectively while the content of ADL in MNG was 25% lower than in ONG. Although the contents of ME and CP were similar, amount of TPDI was 16% lower in PLBC than in SFBC. However, the ADL content was 23% lower in SFBC than PLBC.

3.2. Intake of nutrients

The intakes of nutrients are presented in Table 2 (experiment 1) and Table 3 (experiment 2). The daily DM intake of NG (NDMI), and total intakes of DM (TDMI) and CP (TCPI) were lower by 7, 7 and 29%, respectively ($P < 0.001$), for cows fed the ONG than those fed the MNG diets. In contrast, total intake of OM (TOMI) was 1.3% higher for cows fed the ONG than the cows fed the MNG diets. The TOMI and the TCPI were 1.5 and 0.7% higher, respectively for cows supplemented with the SFBC than those supplemented using the PLBC ($P < 0.001$). The intake of nutrients were higher for the cows in mid- than those in early-lactation ($P < 0.001$). Interaction of napier age with supplement was recorded for TDMI, TOMI and TCPI ($P < 0.001$). In experiment 2, intake of nutrients increased linearly with level of supplementation ($P < 0.001$). The mean of NDMI for the supplemented MNG diets was 15% lower than the MNG only diet ($P < 0.001$) while the TDMI, TOMI and the TCPI were lower by 11, 14 and 24%, respectively ($P < 0.001$), for the MNG only diet than the mean of the supplemented MNG. The rate of substitution of MNG by the PLBC increased linearly with level of supplementation ($P < 0.05$). Although absolute intake of nutrient were higher ($P < 0.05$) for the cows than the heifers, the values expressed per metabolic weight were similar ($P > 0.05$).

3.3. Milk yield and live-weight changes

The milk yield and composition, and live-weight changes are presented in Table 2 (experiment 1) and Table 3 (experiment 2). In experiment 1, the milk yield and milk yield corrected for 4% butter fat (FCM) were 48% lower for the ONG than for the MNG diets ($P < 0.001$). The maturity of NG did not affect the BF and CP contents of milk ($P > 0.05$). However, the SNF content was about 5% lower for the MNG than for the ONG diets ($P < 0.001$). The milk yield and contents of CP and SNF were unaffected by type of supplement ($P > 0.05$). However, the yield of FCM and content of BF were lower by about 3.5 and 4%, respectively ($P < 0.001$) for the PLBC diets than for the SFBC diets. There were slight live-weight gains on animals fed the MNG

Table 2
Feed intake, live-weight change, and milk yields and composition in Friesian cows fed napier grass at medium or old maturity and supplemented with either sunflower or poultry litter based concentrate (experiment 1)[a]

	MNG		ONG		*n*	S.E.D.	NA×SUP	Contrasts		
	SFBC	PLBC	SFBC	PLBC				MNG vs. ONG	SFBC vs. PLBC	EL vs. ML
Live weight (kg)	435.4[a]	438.2[a]	441.0[a]	440.8[a]	8	21.10	NS	NS	NS	NS
LWC (kg cow^{-1} day^{-1})	0.05[a]	0.05[a]	−0.03[b]	−0.02[b]	8	0.01	NS	***	NS	***
Feed intake										
NDMI (kg cow^{-1} day^{-1})	12.2[a]	12.2[a]	11.2[b]	11.1[b]	96	0.10	NS	***	NS	***
TDMI (kg cow^{-1} day^{-1})	15.8[a]	15.7[a]	14.9[b]	14.8[b]	96	0.10	NS	***	NS	***
TDMI (g kg^{-1} W$^{0.75}$)	166.2[a]	166.0[a]	156.1[b]	154.2[b]	96	1.32	***	***	NS	***
TOMI (g kg^{-1} W$^{0.75}$)	136.5[b]	135.3[b]	139.1[a]	136.3[b]	96	1.10	***	***	***	***
TCPI (g kg^{-1} W$^{0.75}$)	16.6[a]	16.5[a]	12.1[b]	11.9[c]	96	0.10	***	***	***	***
Milk yield parameters										
Milk (kg cow^{-1} day^{-1})	11.7[a]	11.4[a]	6.0[b]	5.9[b]	96	0.13	NS	***	NS	***
4% FCM (kg cow^{-1} day^{-1})	11.2[a]	10.7[b]	5.8[c]	5.6[c]	96	0.14	NS	***	***	***
BF (g kg^{-1} milk)	37.3[b]	36.0[c]	38.1[a]	36.2[c]	96	0.04	NS	NS	***	***
CP (g kg^{-1} milk)	27.4[b]	28.7[a]	27.6[b]	27.4[b]	96	0.05	*	NS	NS	NS
SNF (g kg^{-1} milk)	77.2[c]	78.3[bc]	82.4[a]	80.9[ab]	96	0.13	NS	***	NS	NS

[a] *n*, number of observations; S.E.D., standard error of difference between means; MNG, napier at medium maturity (age: 10 weeks; height: 1.3 m); ONG, napier at old maturity (age: 15 weeks; height: 2.0 m); SFBC (SF), sunflower meal-based concentrate; PLBC (PL), poultry litter-based concentrate; LWC, live-weight change; NDMI, napier dry matter intake; TDMI, total dry matter intake; TOMI, total organic matter intake; CP, crude protein; TCPI, total CP intake; FCM, 4% fat corrected milk; BF, butter fat; SNF, solid-not-fat; NS, indicate no significance at $P>0.05$; EL, early-lactation; ML, mid-lactation; NA, age of napier grass; SUP, supplement. [a,b,c] Different superscripts within a row indicate significance ($P<0.05$); *** indicate significance at $P<0.001$.

diets and slight live-weight loss on those fed the ONG diets. However, the type of concentrate supplementation did not affect live-weight changes of the animals. The FCM yields and BF content were higher for the cows in early- than those in mid-lactation ($P<0.05$). However, the SNF and CP contents were unaffected by stage of lactation ($P>0.05$). Although the cows in early-lactation lost weight, those in mid-lactation gained weight. The interaction of age of napier with supplementation was recored only for CP content of milk ($P<0.05$).

In experiment 2, milk yield increased linearly with level of supplementation ($P<0.05$). However, increasing the level of supplementation had a quadratic effect on BF content and a cubic effect on the SNF content ($P<0.05$). The milk yield and the yield of the FCM were about 28% lower for the MNG only diet than for the mean of the supplemented MNG diets ($P<0.001$). The contents of BF, CP, and SNF were lower by 4.5, 3.6 and 8%, respectively ($P<0.001$), for the mean of the supplemented MNG diets than for the MNG only diet. The cows fed MNG only diet lost weight while live-weight gains increased linearly with level of supplementation ($P<0.05$). The milk yield and SNF content were higher while the BF content was lower for the cows than the heifers ($P<0.001$). The CP content of milk was unaffected by parity ($P>0.05$) but the heifers gained more weight than the cows ($P<0.001$).

3.4. Estimated profit margins

Table 4 shows the estimated milk production costs and profit margins. The cost of the PLBC was lower than that of SFBC by 30 and 40% for the rural and peri-urban areas, respectively. In experiment 1, feeding the ONG supplemented with either the SFBC or the PLBC at a daily rate of 3.65 kg per cow resulted in loss of revenue for both rural and the peri-urban areas. The profit was 46 and 8% lower when the MNG was supplemented with the SFBC than with PLBC in the rural and peri-urban areas, respectively.

In experiment 2, the highest profits in both the rural and urban areas were achieved when cows were

Table 3
Feed intake, live-weight change, and milk yields and composition in dairy cows fed napier grass at medium maturity (MNG) supplemented with graded levels of poultry litter based concentrate (experiment 2)[a]

	Treatments						Contrasts	Relationship ($P<0.05$)
	T0	T1	T2	T3	*n*	S.E.D.	Heifers vs. cows	Supplementation
Supplement (% TDMI)	0	6	22	38	–	–	–	–
Live-weight (kg)	433.8[a]	435.8[a]	436.3[a]	436.8[a]	12	9.67	***	–
LWC (g cow^{-1} day^{-1})	−0.02[d]	0.04[c]	0.06[b]	0.08[a]	12	0.01	***	Linear
Feed intake								
NDMI (kg cow^{-1} day^{-1})	13.6[a]	13.2[b]	11.5[c]	10.0[d]	144	0.07	***	Linear
TDMI (kg cow^{-1} day^{-1})	13.6[d]	14.2[c]	15.2[b]	16.4[a]	144	0.07	***	Linear
TDMI (g kg^{-1} $W^{0.75}$)	142.8[d]	148.5[c]	159.5[b]	170.9[a]	144	0.84	NS	Linear
TOMI (g kg^{-1} $W^{0.75}$)	112.8[d]	118.4[c]	130.5[b]	142.8[a]	144	0.67	*	Linear
TCPI (g kg^{-1} $W^{0.75}$)	12.2[d]	13.3[c]	16.1[b]	18.9[a]	144	0.08	**	Linear
SR (kg N kg^{-1} C)	0[c]	0.38[b]	0.56[a]	0.56[a]	144	0.07	NS	Linear
Milk yield parameters								
Milk yield (kg cow^{-1} day^{-1})	7.8[d]	8.9[c]	10.9[b]	13.1[a]	144	0.11	***	Linear
4% FCM (kg cow^{-1} day^{-1})	7.7[d]	8.6[c]	10.6[b]	12.8[a]	144	0.11	***	Linear
BF (g kg^{-1} milk)	39.9[a]	37.9[c]	38.0[c]	38.5[b]	144	0.22	***	Quadratic
CP (g kg^{-1} milk)	30.7[a]	29.9[b]	29.7[b]	29.1[c]	144	0.34	NS	Linear
SNF (g kg^{-1} milk)	86.5[a]	77.9[c]	81.2[b]	79.3[bc]	144	1.02	***	Cubic

[a] N, number of observations; S.E.D., standard error of difference between means; PLBC, poultry litter-based concentrate; LWC, live-weight change; NDMI, napier dry matter intake; TDMI, total dry matter intake; TOMI, total organic matter intake; TCPI, total CP intake; SR, substitution rate; % FCM, 4% fat-corrected milk yield; BF, butter fat; CP, crude protein; SNF, solid-not-fat; MNG only diet (T0); MNG supplemented with 0.91 (T1), 3.65 (T2) and 6.35 (T3) kg DM cow^{-1} day^{-1} of PLBC. [a,b,c,d] Different superscripts within a row indicate significance ($P<0.05$); *** indicate significance at $P<0.001$; NS, indicate no significance at $P>0.05$.

supplemented with the PLBC at a daily rate of 0.91 kg DM cow^{-1}. The mean profit for the supplemented NG was about 22% lower than that for the MNG only diet in the rural areas but the profit from the supplemented MNG was 4% higher than from the MNG only diet in urban areas. Although labour consisted of about 40 and 50% of the total cost in the rural and urban areas, respectively, it was not possible to separate costs of various activities. In practice, a worker perform several daily routine activities such as harvesting, transporting and chopping NG or other forages and feeding to the animals, milking and transporting milk to the market, cleaning stables, weeding and returning slurry (manure and urine) to the fields.

4. Discussion

The chemical composition of the MNG and the ONG in our study was consistent with report by Snijders et al. (1992), Kariuki (1998) and Muia et al. (1999). However, chemical composition values in our study were higher than in other reports (Wouters, 1987; Muinga et al., 1995) probably because of differences in soil fertility, growth period, and management practices and in some cases, the weather. The low intake of nutrients for the ONG than the MNG diets (Table 2) could be ascribed to the high fibre content, low N and low digestibility as forages mature (Van Soest, 1982; Minson, 1990). The higher rumen degradation of young compared to old NG (Kariuki, 1998; Muia et al., 2000b) result in a shorter feed residence period in the rumen, and thus an increased intake. The higher intake of nutrients in cows fed the SFBC than the PLBC diets was a reflection of the higher contents of OM and CP (Table 1). Also, the differences in feed intake could be due to deficiencies or imbalances, rate and extent of degradation and passage rate of particulate matter from the rumen (Wilson and Kennedy, 1996). However, in other studies, the inclusion of PL to replace other conventional protein sources in concentrates did not affect intake or digestibility of the basal diet (Kayongo and Irungu, 1986).

The intake of nutrients in the current study were

Table 4
Estimated cost of milk production from data in experiments 1 and 2[a]

Parameters	Experiment 1				Experiment 2			
	MNG+SFBC	MNG+PLBC	ONG+SFBC	ONG+PLBC	T0	T1	T2	T3
Napier grass								
DMR (kg cow^{-1} day^{-1})	15.25	15.25	14.00	13.88	17.00	16.50	14.38	12.50
CC (cow ha^{-1})	3.39	3.39	3.69	3.72	3.04	3.14	3.60	4.14
Milk (kg ha^{-1})	39.66	38.65	22.14	21.95	23.71	27.95	39.24	54.23
Production costs (Ksh kg^{-1} milk)								
Fertilizer	1.27	1.30	2.04	2.05	2.09	1.78	1.35	0.93
Veterinary	1.42	1.46	2.78	2.82	2.14	1.87	1.53	1.27
Labour								
Rural	4.29	4.40	8.36	8.50	6.41	5.63	4.59	3.89
Urban	7.14	7.33	13.93	14.16	10.68	9.39	7.65	6.38
Concentrate								
Rural	5.61	3.97	10.95	7.67	0.0	1.27	4.15	6.01
Urban	5.61	4.61	10.95	8.91	0.0	1.47	4.82	6.98
Miscellaneous								
Rural	0.63	0.56	1.21	1.05	0.53	0.53	0.58	0.61
Urban	0.77	0.74	1.49	1.40	0.73	0.73	0.77	0.78
Total cost								
Rural	13.22	11.69	25.34	22.09	11.17	11.08	12.20	12.71
urban	16.21	15.44	31.19	29.34	15.66	13.49	16.12	16.34
Profit/loss (Ksh. kg^{-1} milk)								
Rural	1.78	3.31	−10.34	−7.09	3.83	3.92	2.80	2.29
Urban	8.79	9.56	−6.19	−4.34	9.34	11.51	8.88	8.66

[a] MNG, napier at medium maturity (age: 10 weeks; height: 1.3 m); ONG, napier at old maturity (age: 15 weeks; height: 2.0 m); SFBC, sunflower-based concentrate; PLBC, poultry litter-based concentrate; T0, MNG only diet (T1), and MNG supplemented with 0.91 (T1), 3.65 (T2), and 6.35 (T3) kg DM of PLBC.

higher than in other reports (Muinga et al., 1993, 1995) and higher than intake estimates of between 12 and 13 kg DM based on live-weight of the cows (MAFF, 1984). The higher intake than expected may partly be attributed to measurement errors. However, feed intake values in the current study were comparable to values when dairy cows fed NG were supplemented with a cotton seed cake based (Anindo and Potter, 1986). A similar decrease in NDMI as in our study (Table 3) was reported when concentrates (Anindo and Potter, 1986; Muinga et al., 1993) or legumes (Muinga et al., 1995) were used as supplements. In contrast, NDMI increased when when dairy cows were supplemented with copra cake (Muinga et al., 1993). Since the substitution rates were less than 1.0, increasing the amount of concentrate increased the TDMI even though the NDMI was declining. At similar levels of concentrate supplementation, the substitution rates of 0.39 reported by Anindo and Potter (1986) were lower than values in our study. This may be because of the differences in the quality of the basal diet, the supplement, level of supplementation and animal related factors (Grainger, 1990).

The milk yield and yield of FCM were higher on the MNG than the ONG diets mainly because of the higher quality (Table 1), and TCPI (Table 2). As a consequence, cows fed the ONG diets lost more weight than those fed the MNG diets. In addition to variations in voluntary intake, nutrient imbalances, variations in energy density and the efficiency of utilization of digestible or metabolisable energy may contribute to variations in milk yield (Minson, 1990; Clark et al., 1992). Forages with high fibre supply less protein in the small intestines due to low rumen microbial production, a low extent and availability of rumen by-pass protein, and a low apparent protein digestibility than less fibrous forages (Van Bruchem et al., 1989). The MNG diets with less fibre than the ONG diets were expected to support more propionate and less acetate fermentation hence a low content of BF (Sutton et al., 1987). The CP content in milk was unaffected by starch or fibre content of diets (Sutton et al., 1987) in agreement with our results (Table 2). However, for unknown reasons, the content of SNF was higher on the ONG than the MNG.

Since milk yields were unaffected, the higher yields of FCM for the SFBC than for the PLBC was because of the higher BF content (Table 2). The lower BF content for the PLBC diets than for the SFBC diets was because of the reduction in forage degradation due to a possible high passage rate out of the rumen. High levels of minerals in PLBC and the small particle size due to rapid degradation might accelerate the passage of digesta out of the rumen (Silanikove and Tiomkin, 1992). At similar levels of intake, milk yields (not corrected for butter-fat) by ewes (Muwalla et al., 1995) and by dairy cows (Odhuba, 1989) were not significantly different when forages other than NG were supplemented with either PL or conventional protein based concentrates in agreement with our results. Milk yields were higher while yields of the FCM were comparable for dairy heifers on either cotton seed cake or PL based concentrates (Kayongo and Irungu, 1986). In contrast to our results, the BF content in milk was unaffected by supplementation with either PL or sunflower meal based concentrate (Odhuba, 1989).

The high intake of nutrients by cows on the supplemented MNG than the MNG only diet was probably the reason for the observed higher milk yields and weight gains (Table 3). The reported low milk yield and greater weight losses in cows fed MNG only diet than those fed MNG supplemented with concentrates (Anindo and Potter, 1986; Muinga et al., 1993) or legumes (Muinga et al., 1995) were consistent with our results. Since the BF content was lower, the higher yield of FCM for the supplemented MNG than the MNG only diet was mainly because of the higher yield of milk. In agreement with our study, low BF content in milk was reported when cows were fed on supplemented than non-supplemented forages (Rendel, 1990; Stockdale et al., 1990). The supplemented MNG had higher content of rumen fermentable OM and CP hence less acetate and more propionate than the MNG only diet (Muia et al., 2000b). Diets high in starch and with less fibre are associated with lower BF content than those with less starch and high fibre (Sutton et al., 1987). In contrast to our results, CP content in milk was unaffected by fibre content or starch (Sutton et al., 1987).

Use of PLBC was associated with higher profits than the SFBC because of the relatively inexpensive PL. At the prevailing market prices, supplementing cows on the ONG with either PLBC or the SFBC will result in loss of revenue because of the high costs of NG production. In actual practice instead of using the expensive fertilizers, farmers apply manure to their NG and for this reason, feeding of the ONG during the dry seasons may be profitable. Also, since milk prices are usually more favorable during the dry than the wet seasons, supplementing the ONG may be profitable. At the current milk prices, feeding MNG only diet or when supplemented with about 1 kg of the PLBC is more profitable than at high levels of supplementation. Maximum profit was achieved at about 1 kg of supplementation of MNG with PLBC. The decline in profit with level of supplementation beyond 1 kg of PLBC is a reflection of the lower milk yield as NG is substituted by the supplement. However, the high profits in the peri-urban areas can allow the use of high levels of either the SFBC or the PLBC supplementation. For high milk yielding cows, the SFBC will however be preferred because it contains a higher amount of by-pass protein digested in the intestines than the PLBC (Muia et al., 2000b).

The harmful pathogens in PL can completely be eradicated by ensiling (Patil et al., 1993; Kaur et al., 1997). The alternative and inexpensive sun-drying method was also reported to reduce the pathogen risk in PL to levels not harmful to livestock (Kayongo and Irungu, 1986; Muwalla et al., 1995; Jordan et al., 1997; McCann and Martin, 1997). The use of antibiotic (e.g. ionophores) contaminated PL may be associated with cardiac failure leading to death when fed to ruminants (Bastianello et al., 1995). However, growth promoters are not commonly used for poultry production in developing countries. A severe liver damage resulting in mortality rates of between 10 and 20% in beef cattle supplemented at more than 10 kg DM of PL was reported (Silanikove and Tiomkin, 1992). They associated the toxicity of the PL to the absorption of excess NH_3–N from the gut and a low metabolisable energy intake by the animals. It appears therefore that a concentrate constituted using sun-dried PL and a readily degradable energy source in the rumen would therefore pose no pathogenic or toxicity problem to animals. Further, PL contains high levels of macro- and micro-elements (Ben-Ghedalia et al., 1996), and its use as a protein source may reduce the costs of mineral supplementation to dairy cows.

5. Conclusions

The ONG was less nutritive than the MNG diets and as a result, it was not profitable to produce milk at the prevailing market prices of milk and cost of inputs. Since the nutritive value was higher, milk yields were higher in cows supplemented with the SFBC than those supplemented with the PLBC. However, milk production costs were lower in cows supplemented with the PLBC than those supplemented with the SFBC by 46 and 8% in the rural and peri-urban areas, respectively. We concluded that since PL is readily available and inexpensive, a PLBC should be used as an alternative concentrate to reduce costs of supplementation and improve smallholder dairy production on NG diets.

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