Journal of Animal and Veternairy Advances 4 (4): 448-452, 2005

Partial Substitution of Alfalfa Hay with Grass Hay (Sudangrass, Elephant Grass) in Diets for Lactating Dairy Cattle: Dry Matter Intake, Lactation Performance, and Digestive Function

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Abstract: Two trials were conducted to evaluate the effects of partial replacement of alfalfa hay with grass hay (sudangrass and elephant grass) on DMI, lactational performance, and digestive function. Cows were fed a steam-flaked corn-based diet containing (DMB): 1) 49% alfalfa hay; 2) 24% alfalfa and 16% sudangrass; 3) 24% alfalfa, 8% sudangrass, and 8% elephant grass; and 4) 24% alfalfa hay and 16% elephant grass. Diets were formulated to contain 30% NDF (DMB). In trial 1, four lactating Holstein cows (475 kg) with cannulas in the rumen and proximal duodenum were used in a 4 x 4 Latin square experiment to evaluate the treatments effects on digestive function. In trial 2, eight multiparous Holstein cows (567 kg) with 80 ± 8 DIM were utilized in a replicated 4 x 4 Latin square design to evaluate treatment effects of on DMI and lactational performance. There were no treatment effects ($P > 0.10$) on ruminal digestion of OM, and NDF, averaging 51 and 31%, respectively. Microbial efficiency (g microbial N/ kg OM fermented) was greater (20%, $P = 0.07$) for alfalfa (30) than for grass hay substituted diets (25). Nonammonia N flow to the small intestine, as a percentage of N intake (ruminal N efficiency) averaged 101%, and was lower (linear effect, $P < 0.10$) for elephant grass than for sudangrass hay. There were no treatment effects ($P > 0.10$) on total tract digestion of OM, and NDF, averaging 70 and 43%, respectively. Digestible energy content of the diet was lower (5%, $P < 0.05$) for alfalfa hay (64.5%) than for the grass hay substituted diets (67.5%). There were no treatment effects ($P > 0.20$) on DMI, milk yield, averaging 21.8 and 32.2 kg, respectively. Body condition scores were greater (linear, $P > 0.05$) for cows fed elephant grass than for cows fed sudangrass. Substituting grass hay for a portion of the alfalfa hay increased (1.2%, $P < 0.10$) milk fat percentage. We conclude that although substitution of a portion (40%) of alfalfa hay with grass hay in diets for lactating cows may slightly decrease ruminal microbial efficiency, the impact on ruminal and total tract digestion of OM and NDF are small. The feeding value of elephant grass is at least equivalent to that of sudangrass in diets for lactating dairy cows. Grass hay can replace up to 40% of the forage in lactation diets without detrimentally affecting fat corrected milk yield, and milk yield efficiency.

Key words: Forage, Cows, DMI, Performance, Digestion, Metabolism

Introduction

Elephant grass (*Pennisetum purpureum*) is a tall leafy perennial that is characteristic for its high biomass yield (>3000 kg/hectare). The nutrient composition of elephant grass has comparatively little variation between cuttings, even when cut infrequently (Chaparro and Sollenberger, 1997). In this study we are evaluating the feeding value of Promor A, a new elephant grass variety selected for its superior agronomic characteristics (growth, tillering, closing in, ratooning ability, drought and salinity tolerance and ease of cutting), and for its higher CP:NDF ratio. Alvarez *et al*. (2000) observed that in steam-flaked corn-based growing diets containing 20% forage (DMB) as Promor A, alfalfa hay (early bloom), or sudangrass hay, DMI and ADG were greater for diets containing Promor A. The observed net energy value of Promor A (1.19 and 0.63 Mcal/kg for maintenance and gain, respectively) was consistent with predicted values based on its crude protein and fiber content. Virtually all of the improvement in ADG was attributable to superior palatability or acceptability of elephant grass versus sudangrass and alfalfa hay. The potential of elephant grass as partial replacement for conventional forages in diets for lactating dairy cows has not been evaluated. The objective of this study was to evaluate the replacement value of Promor A in diets for lactating dairy cows in terms of DMI, milk yield and composition and ruminal and total tract digestion of OM, NDF, protein, and energy.

Materials and Methods

Trial 1: Four lactating Holstein cows (475 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in a 4 x 4 Latin square experiment. Cows were fed a steam-flaked corn-based diet containing (DMB): T1) 49% alfalfa hay; T2) 24% alfalfa hay and 16% sudangrass hay; T3) 24% alfalfa hay, 8% sudangrass hay, and 8% elephant grass hay; and T4) 24% alfalfa hay and 16% elephant grass hay. Test forages (alfalfa hay, sudangrass hay and elephant grass hay) were ground to pass through a 7.6 cm screen and were added to the mixer as the second step in diet preparation. Diets were formulated to contain 30% NDF (DMB). Experimental diets are shown in Table 1. Chromic oxide (0.35% was added during mixing as an inert digesta marker. Experimental periods consisted of a 10-d diet adjustment period followed by a 4-d collection period. During the collection period duodenal and fecal samples were taken from all cows, twice daily as follows: d 1, 0750 and 1350; d 2, 0900 and 1500; d 3, 1050 and 1650; and d 4, 1200 and 1800. Individual samples consisted of approximately 700 mL duodenal chyme, and 200 g (wet basis) fecal material. Samples from each cow and within each collection period were composited for analysis. On the final day of each collection period, ruminal samples were obtained 4 h after feeding to determine ruminal pH, the rumen of each cows was evacuated, weighed and sampled for DM, and NDF analyses. Upon completion of the trial, ruminal fluid was obtained from all cows and composited for isolation of ruminal bacteria via differential centrifugation (Bergen *et al*., 1968). Samples were subjected to all or part of the following analysis: DM (oven drying at 105 C until no further weight loss); ash, Kjeldahl N, ammonia N (AOAC, 1975); purines (Zinn and Owens, 1986); NDF (Chai and Uden, 1998); chromic oxide (Hill and Anderson, 1958), and starch (Zinn, 1990). Microbial organic matter (MOM) and N (MN) leaving the abomasum is calculated using purines as a microbial marker (Zinn and Owens, 1986). OM fermented in the rumen (OMF) is considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine is considered equal to total N leaving the abomasum minus ammonia-N, MN, and endogenous contributions (0.195 g/kg $BW^{.75}$; Orskov et al., 1986). Dietary NE_{L3x} values were derived from observed DE according to the following relationship (NRC, 2001): NE_{L3x} = 0.674DE – 0.569 (R^2 = .999).The trial was analyzed as a 4 x 4 Latin square. Treatment effects were tested for the following orthogonal contrasts: alfalfa vs grass hay, linear effects of elephant grass substitution with sudangrass, quadratic effects of elephant grass substitution with sudangrass (Hicks, 1973).

Table 1: Composition of experimental diets fed to cows (Trials 1 and 2)[a]

		Sudangrass:elephant grass ratio		
Item	Alfalfa (T1)	100:00 (T2)	50:50 (T3)	00:100 (T4)
Ingredient composition, % (DM basis)				
Alfalfa hay[b]	49.00	24.00	24.00	24.00
Sudangrass hay[c]		16.00	8.00	
Elephant grass (promor A)[d]			8.00	16.00
Steam-flaked corn	34.55	40.70	40.70	40.70
Yellow grease	2.00	2.00	2.00	2.00
Fishmeal	1.00	1.50	1.50	1.50
Canola meal	6.00	8.00	8.00	8.00
Cane molasses	6.00	6.00	6.00	6.00
Limestone	0.30	1.00	1.00	1.00
Trace mineral salt[e]	0.50	0.50	0.50	0.50
Magnesium oxide	0.20	0.20	0.20	0.20
Dicalcium phosphate	0.45	0.10	0.10	0.10
Nutrient composition, DM basis[f]				
DE_{1x}, Mcal/kg	3.21	3.28	-	-
NE_{L3x}, Mcal/kg	1.58	1.62	-	-
Crude protein, %	17.50	15.00	15.40	15.80
UIP, %	6.00	6.15	-	-
Metabolizable methionine, g/d	49.50	52.0	-	-
Metabolizable lysine, g/d	159.00	161.00	-	-
NDF, %	27.80	27.80	26.90	26.00
ADF, %	19.10	17.60	17.00	16.50
NSC, %	41.80	44.30	-	-
Ether extract, %	5.10	5.10	-	-
Calcium,%	1.06	1.00	-	-
Phosphorus,%	0.41	0.40	-	-
Potassium, %	1.22	1.21	-	-
Magnesium, %	0.39	0.40	-	-
Sulfur, %	0.30	0.27	-	-

[a]Chromic oxide (.35%) added to diets in Trial 1 as a digesta marker [b]Alfalfa hay contained (DMB) 2.79% N and 33.9% NDF [c]Sudangrass hay contained (DMB) 1.32% N and 61.4% NDF [d]Elephant grass hay contained (DMB) 1.26% N and 47.3% NDF [e]Trace mineral salt contained: $CoSO_4$, .068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, .052% and NaCl, 92.96% [f]Based on tabular values for individual feed ingredients (NRC, 1996). Tabular values for elephant grass are not provided by NRC (1996)

Trial 2: Eight multiparous Holstein cows (567 kg) with 80 ± 8 DIM were utilized in a replicated 4 x 4 Latin square design to evaluate the effects of treatments on DMI and lactation performance. Experimental diets were the same as those fed Trial 1 (Table 1). All cows received treatment 1 for 21 days before initiation of the trial. Experimental periods consisted of a 21-d diet adjustment period followed by a 4-d collection period (for measurement of treatment effects on DMI and milk production). Cows were housed in individual pens (3 X16 m) with automatic waterers and individual feed bunk, and were provide shade (9 m^2). Cows were milked at 0600 and 1800h. Experimental diets (TMR) were offered twice daily in equal portions (as fed basis), allowing for 10% orts. Feed offered and orts were measured and recorded daily for all cows. Following the pm milking at the beginning and end of each experimental period, cows were weighed, and body condition score (BCS) was recorded (5-point scale; Wildman *et al.,* 1983). Milk samples were collected for eight consecutive milkings. Milk samples from each cow and within each collection period were composited, and analyzed for fat, protein, lactose, and casein (Milko scan FT-120, Foss technology, Eden Prairie,MN). SNF was calculated by difference. Dietary energy values were determined based on observed DMI, average BW, BW change, milk yield and milk composition according to NRC (2001). The DE and NE_L values of elephant grass were determined using the replacement technique:

DE, Mcal/kg = [(DE sudangrass diet – DE elephant grass diet)/0.16]+2.39,

NE_{L3x} , Mcal/kg =[(NE_L sudangrass diet – NE_L elephant grass diet)/0.16]+1.05,

Where 0.16 is the level of test forage in the diet (DMB), and 2.39 and 1.05 are the tabular DE and NE_{L3x} values for sudangrass hay (NRC, 2001). The trial was analyzed as a 4 x 4 Latin square. Treatment effects were tested as in Trial 1.

Results and Discussion

Treatment effects on characteristics of digestion (Trial 1) are shown in Tables 2 and 3. Partial substitution of alfalfa hay with elephant grass increased ruminal pH (linear effect, P < 0.10). The basis for this effect is not certain, but may be related to elephant grass' comparatively high ash concentration (>15%; Alvarez *et al.*, 2000), particularly potassium (> 4.5%; Emanuele and Staples, 1991). Consistent with Alvarez et al. (2000), partial substitution of alfalfa hay with grass hay did not affect (P > 0.10) ruminal digestion of OM, and NDF. Flores et al. (1993) attributed the favorable ruminal digestibility of elephant grass to its comparatively low stem:leaf ratio. Based on NRC (2001) the rate of passage of forage fiber from the rumen is a function of its eNDF content. Grass hays have higher eNDF values than does alfalfa hay (NRC, 2001). Consequently, it was expected that the partial substitution of alfalfa hay for sudangrass or elephant grass would decrease ruminal NDF Kp, and increase ruminal fill. However, this did not occur. The partial substitution of alfalfa hay with grass hay in Trial 1 did not affect (P > 0.10) ruminal NDF K_p, K_d, or fill (Table 3).

Consistent with Alvarez et al. (2000), ruminal microbial efficiency (g MN/ kg OM truly fermented) was greater (20%, P = 0.07) for alfalfa hay than for grass hay substituted diets. Likewise, Varel and Kreikemeier (1994) observed greater ruminal microbial efficiency in cows fed alfalfa versus bromegrass hay. In contrast, Grigsby et al (1991) observed no change in microbial efficiency when substituting tall fescue hay for alfalfa hay. Ruminal degradation of feed N was lower (9%, Table 1) than expected (NRC, 2001), averaging 55%. Ruminal degradation of feed N was similar for sudangrass and elephant grass diets (53 vs 54%, respectively), but tended to be greater (9%; quadratic effect, P < 0.10) for the 50:50 blend of sudangrass hay and elephant grass. Using the difference technique (Zinn et al., 1981), and given that the RUP value of alfalfa hay is 20% (NRC, 2001), the corresponding RUP values for sudangrass and elephant grass are 23 and 11%, respectively.

There were no treatment effects (P > 0.10) on postruminal and total tract digestion of OM, and NDF. Apparent total tract N digestion was greater (linear effect, P < 0.05) for elephant grass than for sudangrass supplemented diets. However, these differences in apparent N digestion are largely explained by differences in N concentration of the diets (digestible CP = 0.93 CP – 3.48; Holter and Reid, 1959). Zinn and Salinas (1999) observed that maximum DMI (DMI_{max}; level of intake at which ruminal physical fill is maximal) is a predictable function of BW, DMI, dietary NDF (%), eNDF as a percentage of dietary NDF, and ruminal NDF digestion (RDNDF, %): $DMI_{max} = (0.075\ BW^{0.75}) / (.010\ NDF_{\%}\ (1 - 0.010\ RDNDF_{\%}) / ((0.77 - 0.00386\ eNDF_{\%NDF} * (0.042\ NDF_{\%} - 0.037 - 0.00031\ NDF_{\%}{}^2)))$. Accordingly, projected DMI_{max} is 11 and 9% greater, respectively, for sudangrass and elephant grass substituted diets than for the basal alfalfa hay diet.

Table 2: Influence of partial substitution of alfalfa for grass hay on digestive function in diets for lactating dairy cattle (Trial 1)

	Treatments [a]				
	Sudangrass:elephant grass ratio				
Item	Control (T1)	100:00 (T2)	50:50 (T3)	00:100 (T4)	SEM
Intake, g/d					
DM	15055.00	15054.00	15347.00	15115.00	122.00
OM	13617.00	13818.00	13657.00	13418.00	119.00
NDF	4065.00	4230.00	3699.00	3643.00	32.00
N	390.00	327.00	384.00	366.00	3.00
Flow to the duodenum, g/d					
Om[c]	9008.00	8345.00	8486.00	8290.00	263.00
NDF	2983.00	2717.00	2576.00	2480.00	209.00
N[bd]	417.00	362.00	401.00	380.00	10.00
NAN[ed]	396.00	345.00	381.00	362.00	9.00
MN	200.00	169.00	197.00	169.00	12.00
Feed N[f]	174.00	154.00	160.00	170.00	5.00
Ruminal pH[f]	5.71	5.78	5.97	5.99	0.11
Ruminal digestion, % of intake					
OM	48.30	51.70	52.60	50.90	2.0
NDF	26.10	35.70	30.40	32.00	5.50
Feed N[g]	55.40	52.90	58.30	53.60	1.70
MN efficiency [ch]	30.40	23.90	27.40	24.80	1.90
Postruminal digestion, % of flow to duodenum					
OM	52.60	50.90	51.10	53.10	2.50
NDF	19.60	13.90	12.50	10.80	7.90
N	70.50	68.80	69.70	69.30	0.60
Total tract digestion, % of intake					
DM	67.10	67.10	66.70	67.90	0.90
OM	68.70	70.30	69.90	71.40	1.00
NDF	41.70	45.40	40.20	43.50	2.50
N[b]	68.60	65.30	68.60	68.40	0.80
DE, Mcal/kg[e]	2.71	2.85	2.78	2.90	0.04
Digestible Energy, %[e]	64.60	67.30	66.80	68.50	1.00

[a] Treatments: Control, 49% alfalfa hay; 100:00, 24% alfalfa hay and 16% sudangrass hay; 50:50, 24% alfalfa hay, 8% sudangrass hay and 8% elephant grass hay and 00:100, 24% alfalfa hay and 16% elephant grass hay

[b] Linear effect of grass hay, p<0.05 [c]Alfalfa vs grass hay, p<0.10 [d] Quadratic effect of grass hay, p<0.10

[e] Alfalfa vs grass hay, p<0.05 [f] Linear effect of grass hay, p<0.10 [g] Quadratic effect of grass hay, p<0.05

[h]Microbial N, g/kg OM truly fermented

Table 3: Treatment effects on the ruminal fill and NDF kinetics in Holstein cows (Trial1)

	Treatments				
Item	T1	T2	T3	T4	SD
Ruminal characteristics, kg					
Ruminal solids fill	8.07	8.47	8.58	7.79	0.31
Ruminal NDF	3.89	4.09	4.36	3.78	0.06
Kinetics of NDF, %/h					
NDF kp	12.10	10.60	10.20	12.00	1.00
NDF kd	4.32	5.67	4.57	5.57	0.80

Digestible energy content of the alfalfa hay diet was lower (5%, P < 0.05) than grass hay diets. This difference was primarily (80%) due to the greater quantity of steam-flaked corn in the grass hay substituted diets (Table 1). Tabular (NRC, 2001) DE values are based on measures at a maintenance level of intake. Observed DE values (Table 2) can be adjusted to a maintenance level index by dividing the observed value by 0.797. Given that the DE value for sudangrass hay is 2.39 Mcal/kg (NRC, 2001), the replacement DE and NE_{L3x} (NE_{l3x} = -0.471 + 0.637 DE; NRC, 2001) values for elephant grass are 2.82 and 1.45 Mcal/kg, respectively. Likewise, Alvarez *et al.* (2000)

Table 4: Influence of treatments on dry matter intake, milk yield and body condition score (Trial 2)

	Treatments				
Item	T1	T2	T3	T4	SD
Cows	8	8	8	8	
LBW, kg					
Initial	571.00	566.00	561.00	568.00	14.00
Final [a]	576.00	581.00	559.00	573.00	21.00
Change	+6	+16	-2	+5	18.0
DMI, kg	21.77	22.08	22.15	21.40	2.73
Milk yield, kg/d	31.71	31.31	33.72	32.20	3.56
FCM (3.5%), kg/d [b]	33.82	33.19	34.30	33.64	4.07
Milk yield/DMI	1.56	1.52	1.59	1.60	0.29
Body condition score[c]	2.84	2.75	2.81	2.88	0.13
Dietary NE_L, Mcal/kg	1.60	1.56	1.60	1.63	0.24

[a]Quadratic effect of grass hay, p<0.10, [b]Fat corrected milk (0.4324 * $Milk_{kg}$)+ (16.21*($Fat_{\%}$ * $Milk_{kg}$/100)),
[c]Linear effect of grass hay, p<0.10

Table 5: Influence of treatments on milk composition (Trial 2)

	Treatments				
Item	T1	T2	T3	T4	SD
Cows	8	8	8	8	
Milk composition,%					
Protein	3.14	3.08	3.14	3.12	0.09
Fat [a]	3.63	3.66	3.67	3.70	0.08
Lactose [b]	4.84	4.79	4.88	4.78	0.10
SNF	8.59	8.58	8.61	8.50	0.25
Total solids	12.22	12.24	12.28	12.20	0.20
Casein	2.51	2.43	2.49	2.46	0.08

[a]Alfalfa vs grass hay, p<0.05 [b]Quadratic effect of grass hay, p<0.10

observed a greater replacement NE_g value (8%) for elephant grass than for sudangrass in growing-finishing diets containing 20% hay. Treatment effects on characteristics of DMI, milk yield and milk composition (Trial 2) are shown in Tables 4 and 5. There were no treatment effects (P > 0.20) on DMI, milk yield, and milk yield efficiency (milk yield, kg/ kg DMI), averaging 21.8 kg, 32.2 kg, and 1.52, respectively. Likewise, there were no treatment effects on BW change, averaging 6 kg. However, body condition score was greater (linear effect, P < 0.05) in cows fed elephant grass than for cows fed sudangrass substituted diets. Substituting grass hay for a portion of the alfalfa hay increased (1.3%; P < 0.10) milk fat. This finding is consistent with the greater ruminal pH observed in Trial 1 (Table 2) with grass hay substituted diets. Increased milk fat percentage has been a consistent response to partial substitution of alfalfa hay with grass hay in lactation diets (Beauchemin *et al.*, 1997; Cherney, 2000). There were no treatment effects on dietary NE_{L3x}, averaging 1.60, in good agreement with tabular values (Table 1). As with Trial 1, lactational performance response demonstrates that the energy value of elephant grass is at least equivalent to that of sudangrass as a partial replacement for alfalfa hay.

Conclusion

Substitution of a portion (40%) of alfalfa hay with grass hay in diets for lactating cows may slightly decrease ruminal microbial efficiency. However, the impact on ruminal and total tract digestion of OM and NDF are small. The feeding value of elephant grass is at least equivalent to that of sudangrass in diets for lactating dairy cows and can replace up to 40% of the forage without detrimentally affecting fat corrected milk yield, and milk yield efficiency. Due to differences in NDF content of alfalfa hay and grass hays, the substitution with grass hay results in less total forage, creating “space” in the formulation for alternative feed ingredients.

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