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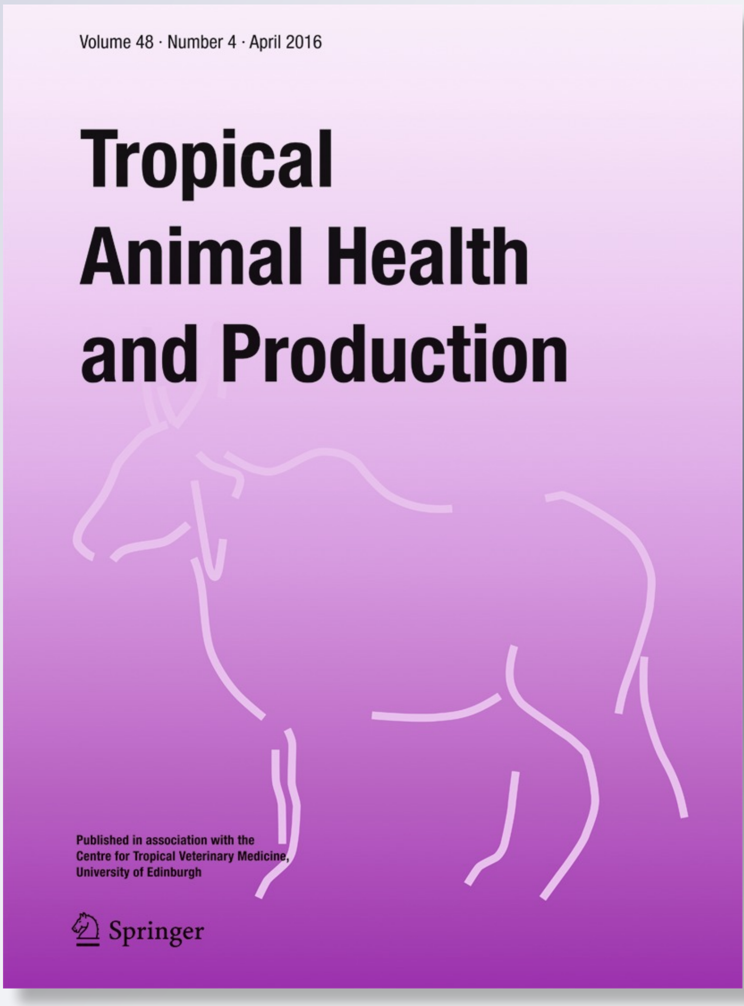

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REGULAR ARTICLES

Effects of inclusion levels of banana (*Musa spp.*) peelings on feed degradability and rumen environment of cattle fed basal elephant grass

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Abstract The effect of feeding varying banana peeling (BP) levels on rumen environment and feed degradation characteristics was evaluated using three rumen fistulated steers in four treatments. The steers were fed BP at 0, 20, 40, and 60 % levels of the daily ration with basal elephant grass (EG) to constitute four diets. Maize bran, cotton seed cake, and *Gliricidia sepium* were offered to make the diets iso-nitrogenous. The nylon bag technique was used to measure BP and EG dry matter (DM), crude protein (CP), and neutral detergent fiber (NDF) degradabilities at 0, 6, 12, 24, 48, 72, 96, and 120 h. Rumen fluid samples were collected to determine pH and volatile fatty acid (VFA) concentrations. Effective DM, CP, and NDF degradabilities of BP ranged between 574 and 807, 629–802, and 527–689 g/kg, respectively, being lower at higher BP levels. Elephant grass degradability behaved similarly with relatively high effective CP degradability (548–569 g/kg) but low effective DM and NDF degradability (381–403 and 336–373 g/kg, respectively). Rumen pH and VFA reduced with increasing BP in the diets. Rumen pH dropped to 5.8 and 5.9 at the 40 and 60 % BP feeding levels, respectively. Banana peelings were better degraded than EG but higher BP levels negatively affected feed degradability and rumen environment.

Keywords Banana peelings · Degradability · Elephant grass · Rumen pH · Volatile fatty acids

Introduction

Uganda is endowed with many food crops whose residues are potential feeds especially in urban/peri-urban faming systems which have limited pastureland. Elephant grass (EG) is the commonest feed, but it is grown on small plots because of space limitation. Feeding EG with readily available residues like banana peelings (BP) can reduce the problem of feed scarcity. Bananas occupy the largest cultivated area in Uganda, making Ugandans the world's greatest consumers of bananas (Nowakunda and Tushemereirwe 2004). The commonest bananas are the cooking type/plantains from which plenty of BP are generated. There is sparse literature on the feeding value and fermentation characteristics of BP. Knowing feed chemical and degradation characteristics enables correct formulation of feedstuffs leading to adequate prediction of animal performance.

Banana peelings are low in fiber (Emaga et al. 2011); hence, they are readily degradable. Feeding large quantities of BP, however, necessitates supplementation with large amounts of concentrates since BP are low in protein (Nambi et al. 2001). However, rapidly fermentable feeds reduce rumen pH (O'Mara et al. 1997) which lowers microbial activities. Rumen pH should be ideal for optimal growth of bacteria to result into favorable volatile fatty acid (VFA) patterns and yield and effective feed degradability (Cerrato-Sánchez et al. 2007).

Elephant grass degradability varies with diets (Kabi et al. 2005). Therefore, there is need to determine EG and BP degradability to know how best to feed them to optimize animal productivity. The objective of this study, therefore, was to determine

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the effect of varying BP levels on dry matter (DM), crude protein (CP), and neutral detergent fiber (NDF) degradabilities of EG and BP and their effect on rumen environment.

Materials and methods

This study was conducted at Makerere University Agricultural Research Institute using three rumen fistulated steers. Elephant grass was offered ad libitum while BP were offered at 0, 20, 40, and 60 % levels of the total ration to constitute four diets (Table 1). Maize bran (MB), cotton seed cake (CSC), and *Gliricidia sepium* (GS) were added to make the diets iso-nitrogenous. The first 14 days on each diet were for adaptation, the 15th day for rumen fluid collection, and the last 6 days for incubation of nylon bags. Rumen fluid was sampled 6 h after morning feeding during each treatment and immediately strained through cheesecloth and the pH read with a pH meter. The samples were then put into plastic containers, and three drops of concentrated HCl were added. They were then refrigerated and later analyzed for VFA.

The nylon bag technique (Osuji et al. 1993) was used to determine EG and BP DM, CP, and NDF degradabilities. Dried samples of the test feeds were milled to pass through a 2-mm screen prior to incubation. Approximately 5 g of each feed was weighed into each nylon bag. Triplicate bags for each feed were incubated in each of the steers, making a total of 9 and incubated for 0, 6, 12, 24, 48, 72, 96, and 120 h using sequential addition. The 0-h bags were not incubated but were thoroughly hand washed with the other bags after incubation. The bags were then dried in a forced draft oven at 60 °C for 48 h, cooled in a desiccator, weighed, and then pooled by feed, incubation time, and animal at the end of each treatment. Disappearance of DM, nitrogen (N), and NDF from the nylon bags was described by the exponential model by McDonald (1981) with lag time to data using the nonlinear procedure of SAS (1990). The model describing degradation profile is shown as follows: $P = a + b\ (1 - e^{-c\ (t - tl)})$.where P = degradability of DM, OM, N, or NDF at time (t), a = zero time intercept (rapidly soluble fraction), b = slowly but potentially degradable fraction, c = rate of degradation at which fraction b will be degraded per hour, and tl = lag time. The resulting constants were used to estimate effective degradability following Ørskov and McDonald (1979) equation.

For feed analyses, feed samples were oven-dried at 60 °C for 48 h, ground through a 1-mm sieve, and later analyzed for N, NDF, and ash. DM of the feeds and nylon bag residues were determined in a forced draft oven by drying at 60 °C to constant weight. Ash and N were determined according to AOAC (1990) while NDF was determined according to Van Soest and Robertson (1985). The VFA concentrations were determined using gas chromatography. The DM, CP, and NDF degradabilities were analyzed with a mixed model of SAS (1990) according to Littell et al. (1996). Periods were included in the model below as independent variables:

$$Y_{ijk} = \mu + \alpha_i + \tau_k + (\alpha\tau)_{ik} + d_{ij} + e_{ijk}$$

where Y_{ijk} = disappearance of chemical component at period k on animal j in treatment group i, μ = overall mean, α_i = fixed effect on treatment i, τ_k = fixed effect of period k, $(\alpha\tau)_{ik}$ = fixed interaction effect of treatment i with period k, d_{ij} = random effect of animal j in treatment group i, and e_{ijk} = random error at period k on animal j in treatment i. Least square means were then separated using the probability of difference option of SAS. Rumen pH and VFA data were analyzed using Genstat by Leng and Payne (1996).

Results

Elephant grass had higher levels of all components than BP (Table 2). Among supplements, CSC had higher DM and CP than the other two while GS had higher NDF and ash than MB and CSC.

DM degradation characteristics of BP are presented in Table 3. The zero time intercept "**a**" was similar across diets

Table 1 Feed composition of the experimental diets (DM basis) used to evaluate degradability

	Diets			
	I	II	III	IV
Ingredient (%)				
Banana peelings	0	20.0	40.0	60.0
Elephant grass	78.7	54.5	30.2	6.0
Gliricidia sepium	4.3	5.1	6.0	6.8
Cotton seed cake	8.5	10.2	11.9	13.6
Maize bran	8.5	10.2	11.9	13.6

Table 2 Chemical composition (g/kg DM) of the feeds used in the degradability study

	The different feeds				
	BP	EG	MB	CSC	GS
Component					
Dry matter	867	918	888	890	882
Crude protein	58	106	127	413	248
Neutral detergent fiber	456	730	304	247	589
Ash	73	94	50	73	111

BP banana peelings, *EG* elephant grass, *MB* maize bran, *CSC* cotton seed cake, *GS* gliricidia

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Table 3 DM degradability characteristics (g/kg) of BP in steers fed diets with varying BP levels

Parameters	Percentage of BP in the diets				SEM
	0	20	40	60	
a	345	346	346	344	1.3
b	521[b]	584[a]	433[c]	439[c]	2.7
a + *b*	866[b]	930[a]	779[c]	783[c]	2.1
c	1.37[a]	1.12[b]	0.34[c]	0.33[c]	0.06
tl	9.7	8.2	2.7	3.2	2.83
ED	772[b]	807[a]	577[c]	574[c]	2.88

[abc] Means within a row with different letters are significantly different ($P \leq 0.05$)

a zero time intercept, *b* insoluble but slowly degradable fraction, *a* + *b* potential degradability, *c* rate of degradation of *b* component, *tl* time lag (h), *ED* effective degradability, *SEM* standard error of the least square means

Table 5 NDF degradability characteristics (g/kg) of BP in steers fed diets with varying BP levels

Parameter	Percentage of BP in the diets				SEM
	0	20	40	60	
a	305	297	277	290	10.2
b	576[ab]	626[a]	466[b]	589[ab]	35.0
a + *b*	881[a]	923[a]	764[b]	879[ab]	35.6
c	0.64[a]	0.54[a]	0.45[ab]	0.22[b]	0.08
tl	7.4	5.0	12.6	3.0	4.99
ED	685[a]	689[a]	569[b]	527[c]	11.9

[abcd] Means within a row with different letters are significantly different ($P \leq 0.05$)

a zero time intercept, *b* insoluble but slowly degradable fraction, *a* + *b* potential degradability, *c* rate of degradation of *b* component, *tl* time lag (h), *ED* effective degradability, *SEM* standard error of the least square means

while the insoluble but slowly degradable fraction "**b**," potential degradability "**a + b**," and effective degradability (ED) were highest ($P \leq 0.05$) at the 20 % BP level. The "**a**" and "**tl**" parameters of CP degradation of BP were not affected by diets while "**b**" and "**a + b**" varied in a similar manner (Table 4). The "**c**" component differed across diets. Effective protein degradation was higher ($P \leq 0.05$) at the 0 and 20 % BP levels. With BP NDF characteristics, ED was higher ($P \leq 0.05$) at lower BP levels while "**a**" and "**tl**" were not affected (Table 5). The "**c**" component decreased at higher BP levels.

Except for "**a**," the other DM EG degradation parameters differed ($P \leq 0.05$) across diets (Table 6). Both "**b**" and "**a + b**" reduced as BP were increased. The "**c**" component was higher ($P \leq 0.05$) and similar at higher BP levels while **ED** was lowest at these levels. The "**a**" component was not affected with EG CP degradation (Table 7). Both "**b**" and "**a + b**" varied in a similar manner across diets while "**c**" varied in a reverse manner. Effective degradability was higher at lower BP levels ($P \leq 0.05$). For NDF degradability, only "**a**" was not affected by the diets (Table 8).

Varying BP levels affected rumen environment (Table 9). The diet without BP had the highest pH while those with BP had similar pH ($P \leq 0.05$). Addition of BP reduced ($P \leq 0.05$) acetate and propionate. Diet with 60 % BP had the lowest acetate although this level did not differ from that at the 40 % BP level while propionate was lowest at the 40 % BP level. Butyrate was highest at the 40 % BP level.

Table 4 CP degradability characteristics (g/kg) of BP in steers fed diets with varying BP levels

Parameter	Percentage of BP in the diets				SEM
	0	20	40	60	
a	459	462	467	477	7.8
b	464[a]	404[b]	333[c]	343[c]	8.0
a + *b*	923[a]	865[b]	800[c]	820[c]	13.1
c	0.75[b]	1.63[a]	0.33[c]	0.27[c]	0.10
tl	2.1	15.3	3.9	7.1	5.75
ED	790[a]	802[a]	640[b]	629[b]	7.83

[abcd] Means within a row with different letters are significantly different ($P \leq 0.05$)

a zero time intercept, *b* insoluble but slowly degradable fraction, *a* + *b* potential degradability, *c* rate of degradation of *b* component, *tl* time lag (h), *ED* effective degradability, *SEM* standard error of the least square means

Table 6 DM degradation characteristics (g/kg) of EG in steers fed diets with varying BP levels

Parameter	Percentage of BP in the diets				SEM
	0	20	40	60	
a	167	169	168	166	2.3
b	467[a]	460[a]	416[b]	399[c]	3.8
a + *b*	634[a]	629[a]	584[b]	565[c]	2.3
c	0.30[b]	0.31[b]	0.34[a]	0.35[a]	0.01
tl	1.6[b]	1.0[b]	17.8[a]	9.7[ab]	3.35
ED	399[a]	403[a]	389[b]	381[b]	2.67

[abcd] Means within a row with different letters are significantly different ($P \leq 0.05$)

a zero time intercept, *b* insoluble but slowly degradable fraction, *a* + *b* potential degradability, *c* rate of degradation of *b* component, *tl* time lag (h), *ED* effective degradability, *SEM* standard error of the least square means

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Table 7 CP degradability characteristics (g/kg) of EG in steers fed diets with varying BP levels

Parameter	Percentage of BP in the diets				SEM
	0	20	40	60	
a	323	326	327	327	02.0
b	653[a]	641[a]	457[b]	467[b]	8.8
a + *b*	976[a]	966[a]	782[b]	793[b]	7.7
c	0.18[b]	0.18[b]	0.30[a]	0.27[a]	0.01
tl	14.6	15.5	18.0	16.1	3.91
ED	565[a]	569[a]	553[b]	548[b]	34.9

Partial prelimininary communication (Nambi-Kasozi et al. 2009)

[ab] Means within a row with different letters are significantly different ($P < 0.05$)

a zero time intercept, *b* insoluble but slowly degradable fraction, *a* + *b* potential degradability, *c* rate of degradation of *b* component, *tl* time lag (h), *ED* effective degradability, *SEM* standard error of the least square means

Table 9 Rumen pH and VFA concentrations of steers fed diets with varying BP levels

Parameter	Percentage of BP in the diets				LSD
	0	20	40	60	
pH	6.7[a]	6.1[b]	5.8[b]	5.9[b]	0.47
Molar % of VFA					
Acetate	54.6[a]	53.4[a]	48.6[b]	46.8[b]	3.40
Propionate	26.2[a]	24.3[b]	20.0[d]	21.8[c]	0.86
n-Butyrate	11.1[d]	22.3[b]	23.4[a]	17.5[c]	0.76

[abcd] Means within a row with different letters are significantly different ($P < 0.05$)

Discussion

The CP in EG was close to that obtained elsewhere (Nambi et al. 2001) while NDF was close to 720 g/kg reported by Ferreira et al. (2014). The relatively high CP in EG makes it a good feed. The BP CP was close to that reported by Nambi et al. (2001) and Tegene (2009). Banana peelings had lower NDF than EG, implying that though they are low in CP, they are easily degradable, hence good feeds if strategically supplemented. Dahlan and Iskandar (2013) and Okoruwa et al. (2013) also reported higher NDF in EG than in plantain peels. The lower fiber in BP is most likely the reason they were better degraded than EG.

Table 8 NDF degradability characteristics (g/kg) of EG in steers fed diets with varying BP levels

Parameter	Percentage of BP in the diets				SEM
	0	20	40	60	
a	145	146	148	144[b]	1.2
b	750[a]	705[b]	519[c]	520[c]	3.1
a + *b*	894[a]	851[b]	667[c]	664[c]	3.5
c	0.13[d]	0.14[a]	0.17[c]	0.18[a]	0.01
tl	3.2[b]	9.6[a]	1.6	5.4[ab]	1.66
ED	366[b]	373[a]	336[d]	339[c]	0.94

[abcd] Means within a row with different letters are significantly different ($P \leq 0.05$)

a zero time intercept, *b* insoluble but slowly degradable fraction, *a* + *b* potential degradability, *c* rate of degradation of *b* component, *tl* time lag (h), *ED* effective degradability, *SEM* standard error of the least square means

The BP were better degraded than reported elsewhere with respect to DM potential degradability and NDF ED. Monção et al. (2014) reported DM potential degradability and NDF ED of 698 and 223 g/kg, respectively, for dessert-type peels. This implies that plantain peels (PP) are better feeds than dessert-type peels. Better degradability of PP is mostly likely due to the fleshy fruit parts taken up with the peels since peeling is done before the fruits ripen.

Breakdown of feeds varies with animals' diets (Spencer et al. 1988). As BP in the diets were increased, so was the quantities of supplements to balance the diets since BP are low in most nutrients. The DM ED for BP was higher when they were incubated in steers fed diets with lower BP levels. The lower ED at higher BP levels is attributed to lower microbial activities at lower pH. With lowered microbial activities, less feed is degraded. Higher BP amounts/concentrates were quickly fermented leading to accumulation of VFA which lowered rumen pH. Rapidly fermented feeds lead to lowered pH (O'Mara et al. 1997). The lower pH with increasing BP levels is probably also due to the remaining BP contents that contain starch and sugars (Sharaf et al. 1979). High starch and sugars levels cause rumen pH drops (Guo et al. 2013). Crude protein and NDF degradability of BP also varied similarly like DM degradability due to the above factors. In a related study in which Dahlan and Iskandar (2013) evaluated PP in replacing EG, DM digestibility increased with decreasing PP proportions. The optimum PP proportion was obtained at 28 % among inclusion levels of 0, 25, 40, 50, and 75 %. In agreement with this study, these authors concluded that excessive use of PP causes negative effects to animals. Dormond-Herrera et al. (1998), however, observed no difference in degradability of *Pennisetum clandestinum* and *Cynodon nlemfluensis* in cows fed 0, 7, 14, and 21 kg of PP/cow/day probably due to the lower PP levels in their study. The lower degradability in this study was observed at higher BP levels.

Effective EG protein degradability was close to values obtained by Kabi et al. (2005). Degradability of EG reduced at higher BP levels, implying that in feeding concentrates/low

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fiber feeds, caution should be taken to avoid rapid degradability which lowers rumen pH. Fiber-digesting bacteria growth is favored with pH from 6.0 to 6.8 (Mould et al. 1984). When pH lowers, animals suffer subacute acidosis which greatly lowers microbial activities subsequently reducing degradability. This explains why NDF degradability was reduced in diets with pH < 6.

Rumen pH was lowered as BP and concentrates in the diets were increased. When animals consume readily degradable feeds, rumen pH falls below 6 (Cerrato-Sánchez et al. 2007). With lowered pH, effects like inhibition of ruminal cellulolysis (Mould et al. 1984) and disruption of microbial populations result. Cellulose fermentation inhibition is due to limited bacterial adhesion, cellulose hydrolysis, microbial growth, or a combination of these factors (Mouriño et al. 2001). Better rumen fiber fermentation leads to higher feed digestibility/degradability. Fiber digestion decreases when pH falls below 6.2 (Calsamiglia et al. 1999). With reduced fiber fermentation, acetate, the main VFA from fiber fermentation, also reduces (Cerrato-Sánchez et al. 2007) as was observed in this study. However, propionate production in this study also reduced at lower rumen pH unlike in other studies (Bramley et al. 2007; Cerrato-Sánchez et al. 2007). This could be due to reduced fibrolytic bacteria activities at low pH resulting into lower succinate and subsequently, lower propionate production. Many fiber-digesting bacteria produce large quantities of succinate an intermediate later converted to propionate. The lower propionate could also be due to the negative effects like low ammonia (Bramley et al. 2007) and reduced rumen motility (Underwood 1992) induced in acidotic animals. Such effects reduce fermentation by all microbes. Ammonia is required for microbial growth while rumen motility aids fermentation. It is therefore necessary that diets maintain a pH above 6. Interference in microbial activities at lower pH led to lower VFA at higher BP levels.

In conclusion, BP were better degraded than EG which makes them a good complementary feed to EG. However, utilization of BP necessitates strategic supplementation since they are low in protein. Feeding higher BP levels reduced rumen pH, feed degradability, and VFA production. It is therefore important to take measures in formulating diets with large BP amounts to prevent reduced pH which leads to lowered microbial activities subsequently lowering animal performance.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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