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EFFECT OF MATURITY ON CHEMICAL COMPOSITION, PHENOLICS AND AMINO ACIDS CONTENT AND RUMEN DEGRADABILITY OF *Sorghum almum*

[EFECTO DE LA MADUREZ EN LA COMPOSICIÓN QUÍMICA, CONTENIDO DE FENOLES Y AMINO ÁCIDOS Y DEGRADABILIDAD RUMINAL DE *Sorghum almun*]

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SUMMARY

The effect of advancing maturity on chemical composition and *in sacco* rumen degradability of *Sorghum almum* was investigated. The grass was established and harvested at 6, 10 and 14 weeks-old. Herbage samples were analyzed for dry matter and chemical constituents following standard procedures. *In sacco* (Nylon bag) rumen degradability was done using 6 wethers (Age: 8 mo., 20.6 kg LW) and fed a ration comprising of 3:1 fresh *S. almum* (DM: 148.9 g DM and CP: 109.8 g kg^{-1} DM) and *Medicago sativa* hay (DM: 903.1 g DM and CP: 188.6 g kg^{-1} DM). Nylon bags containing 5 g DM were incubated (0, 12, 24, 36 and 48 h incubation periods). Dry matter, NDF, ADF and ADL content increased by 72.98, 62.64 and 56.5% respectively between 6 and 14 weeks. In contrast, CP, EE, total phenolics and RFV decreased by 66.67, 73.42, 25.25 and 38.65% respectively over the same period. Concentration of arginine, methionine, lysine and total amino acids declined by 66.02, 78.26, 46.44 and 63.41% respectively. DM, OM and CP degradability also declined with advancing age of the grass ($P < 0.01$; $P < 0.0001$ and $P < 0.0001$, respectively). It was therefore concluded that advancing maturity adversely affected the quality of *Sorghum almum.*

Key words: Sheep, Amino acids, Total phenolics, Effective degradability.

RESUMEN

Se estudio el efecto de la madurez sobre la composición química y la degradabilidad ruminal de *Sorghum almum*. El pasto fue cosechado a la 6, 10 y 14 semanas de crecimiento. La degradabilidad ruminal fue medida en 6 borregos (8 meses edad, PV 20.6 kg) con canula ruminal y alimentados con *S. almum* fresco (148.9 g MS y PC: 109.8 g kg^{-1} MS) y heno de *Medicago sativa* (903.1 g MS y PC: 188.6 g kg^{-1} MS) en proporción 3:1. Se incubaron bolsas de nylon con 5 g de MS (0, 12, 24, 36 y 48 h). El contenido de MS, FDN, FDA y ADL incrementó en 72.98, 62.64 y 56.5% respectivamente entre la 6ª. y 14ª. semana. En contraste, PC, EE, fenoles y RFV disminuyeron en 66.67, 73.42, 25.25 y 38.65% respectivamente. Las concentraciones de arginina, metionina, lisina y total de amino ácidos declinaron en 66.02, 78.26, 46.44 y 63.41% respectivamente. La degradabilidad de la MS, MO y PC se redujo con la edad ($P < 0.01$; $P < 0.0001$ y $P < 0.0001$, respectively). Se concluye que la madurez afecta de manera adversa la calidad del *Sorghum almum.*

Palabras clave: Ovinos, Amino ácidos, polifenoles totales, degradabilidad efectiva.

INTRODUCTION

Though it is classified as a terrestrial weed in some countries (Minnesota DNR, 1999), Columbus grass (*Sorghum almum*) is an important source of nourishment for ruminant livestock in many production systems. Due to its high forage characteristics (Kallah et al., 1999; Muhammad, 1993; Muhammad et al., 1994), drought (Gohl, 1981) and disease resistance (Rich et al., 2004; Reed et al., 2002), *Sorghum almum* is particularly an attractive forage crop for ruminant livestock production in many tropical and subtropical regions. In these regions, *Sorghum almum* is widely recognized and valued for its high yield of palatable herbage (Reeds, 1976; Bogdan, 1977; Myoya et al., 1987) suitable for

ensiling (Kallah et al., 1997; Kallah et al., 1999; Aminah et al., 2000; Chin, 2002), haymaking (Duke, 1983) and grazing (Catchpoole, 1972). In Argentina where it was first developed, *Sorghum almum* is used almost exclusively for grazing (Duke, 1983). Its chemical composition (Kallah et al., 1999; Chin, 2002) and digestibility (Rodriquez, 2005) is closely comparable to those of commonly cultivated high quality tropical grass fodder crops (Muia, 2000; Keftasa, 1990). Excellent performance of ruminant livestock on *Sorghum almum* based diets has also been recorded (Sheridan et al., 2003; Aminah et al., 2000), which in turn suggests that, with a sound feeding management, the reported presence of prussic acid (Gohl, 1981) posses no major risk to ruminants. Its economic contribution in smallholder peri-urban dairy production systems has also been documented (Agyemang et al., 1998). Despite its long history in the country (Orodho, 2006), cultivation of *Sorghum almum* on smallholder farms in Kenya has remained low. The scanty literature on its chemical composition, total phenolic and amino acid profile and rumen degradability characteristics at different morphological stages and under different edaphic factors under Kenyan farming condition is presently being seen as the major drawback, to its adoption by smallholder farmers. This paper reports the results of the study conducted to determine the effect of advancing maturity on these quality aspects and relative feed value. The overall objective was to generate technical information that would guide *Sorghum almum* utilization in Kenya and other tropical and sub-tropical regions.

MATERIAL AND METHODS

Forage establishment and sampling

The study was conducted at the forage experimental unit of the National Animal Husbandry Research Centre in Naivasha Kenya (soil: 216 g Ca kg^{-1} DM, 113 mg P kg^{-1} DM and pH = 7.38). The centre is located on grid 0^o 40' S and 36^o 26' E at an altitude of 1940 metres above sea level (Jaezhold and Schmidt, 1982) with a mean temperature of 18^o C. To study the effect of advancing maturity on concentration of chemical constituents and rumen degradability of Columbus grass (*Sorghum almum*), 36 plots (size: 2 x 2 sq. m separated by 30 cm weed free guard rows) were demarcated and further divided into 3 similar units (N = 12). In each plot, 5 rows of 2 m length, 30 cm apart and about 4 cm deep were drilled. A total of 25 g of seed (viability approx: 80%) were then sown with each line receiving 5 g of seed (evenly sprinkled). The plots were later harvested at the age of 6, 10 and 14 weeks each time at 5 cm above soil. Representative grabs of the freshly harvested forage were made per plot, chopped to pieces of 2 cm length, mixed thoroughly and 2 composite samples (500 g each) were taken for dry matter (DM) determination, chemical analyses, amino acids profiling, total phenolic assaying and rumen degradability study.

Animals and diets

Six rumen fistulated wethers aged about 8 months with a mean live weight (LW) of 20.6 kg were used. Prior to the study, all the wethers were drenched with a broad-spectrum anthelminth, Valbazen (Smith-kline, Switzerland) and sprayed with an accaricide to eradicate both internal and external parasites respectively, they were then weighed, ear-tagged and then placed into well-ventilated individual metabolic cages (size: 120 cm long x 50 cm wide x 90 cm high) raised 60 cm above a concrete floor and equipped with feed and water troughs. A ration comprising of 3:1 fresh 8 – 10 weeks old Columbus grass (*Sorghum almum*: 148.97 g DM; 109.87 g CP kg^{-1} DM, 652.97 g NDF kg^{-1} DM, 346.6 g ADF kg^{-1} DM and Lucerne hay (*Medicago sativa*: 903.1 g DM; 188.6 g CP kg^{-1} DM, 426.8 g NDF kg^{-1} DM, 318.1 g ADF kg^{-1} DM), both chopped to a particle size of 2 cm, was offered *ad libitum* twice daily in equal amounts at 07.30 h and 16.30 h beginning 14 days before the start of the trial. They also had a free access to a balance mineral lick and clean drinking water.

In sacco degradability

Dry matter (DM), Organic matter (OM) and crude protein (CP) degradation characteristics were determined using the nylon bag technique as described by Ørskov and McDonald (1979) and Ørskov et al. (1980). The feed materials were dried at 65 °C for 24 hours and thereafter grounded in a Christy and Norris mill to pass a 2.5 mm sieve (Abdulrazak and Fujihara, 999). Representative samples of 5 g each were weighed (in duplicates) into clean well-labeled and weighed nylon bags of pore size 40 µm and inner size of 6.5 cm x 12 cm. The bags were inserted into the rumen (12 bags per wether) all at the same time and withdrawn in a sequentially at: 12, 24 36 and 48 h. Immediately after withdrawal, the bags were dipped into cold water to stop further microbial activity and then rinsed by cold tap water to remove the rumen matter from the outside of the bags. Thereafter, the bags were washed gently under slow running tap water for 30 minutes, till the water was clear. Finally, they were dried at 65^oC for 48 hours in a forced air oven, desiccated for 30 minutes and then weighed. To determine the washing loss 2 additional bags (0 h) containing 5 g each for each of the test feeds were soaked in water bath kept at 39^oC for 1 h and thereafter underwent the same washing and drying procedures as the incubated bags. The *in sacco* dry DM, OM and CP digestibility at different incubation periods were determined as described by Ørskov et al. (1980).

Laboratory analyses

The nylon bags (containing residue) were dried in a forced-air oven at 65°C for, 48 h after which residue weights were calculated. Both forage samples and residues were grounded to pass 1 mm screen and stored in airtight plastic bottles while awaiting chemical analyses. Ash was determined (AOAC, 1990, ID 942.05) and micro-Kjeldahl N in feed and residues (AOAC, 1990, ID 954.01). Crude protein was calculated as Kjeldahl N x 6.25. Neutral-detergent fibre (NDF), acid-detergent fibre (ADF) and acid-detergent lignin (ADL) were determined by the procedures of Goering and Van Soest (1970) and Van Soest and Robertson (1985). Ether extract (EE) was determined by extracting the sample with petroleum ether using a Gerhart Soxtherm 2000 Automated (AOAC, 1990, ID 920.39). Representative samples taken from the various harvests (dried at 40°C and grounded to pass 1 mm screen) were also assayed for total phenolics (TP) by the Folin assay method (Folin – Denis method) as described by Waterman and Mole (1994) and Palm and Rowland (1997). Linear regression was used to construct a standard curve relating absorbance (760 nm) of the Folin assay reaction mixture to the known concentration of tannic acid (µg) (standard). Similarly, representative dry samples (approx. 5 µg) from forage harvested at different maturity stages were also assayed for both essential and non-essential amino acids (AA) concentration according to AOAC (1990, ID 994.12 Llames and Fontaine 1994).

Statistical analysis and calculations

The chemical constituents in the 3 grass harvests were analysed as a randomised complete block design using SAS (2002). The statistical model used was: $Y_i = \mu + A_i + e_i$; where Y_i = the concentration of the chemical constituents measured; μ = overall mean, A_i = age at harvest and e_i = random experimental error. The Proc GLM was used to perform the analysis of variance (ANOVA) and means were contrasted with significance assumed when P = 0.05 (SAS, 2002). Linear and quadratic regression functions were fitted using SPSS (2003) to describe the exhibited change patterns. Data for *in sacco* degradation were fitted to the first order kinetics defined by the exponential equation of the form $p = a + b (1 – e^{-ct})$; (Ørskov and McDonald 1979; McDonald, 1981): where p represents degradation of DM, OM and CP at time t; 'a' – readily soluble fraction; 'b' – slowly degradable fraction; 'c' is the rate of degradation of 'b' per h and 'a + b' is potential degradation. Effective rumen degradation of the forage components was calculated as: $ED = a + (b \times c) / (c + k)$, assuming the rumen fractional outflow rates (k) of 2, 5 and 8% h^{-1} (Ørskov and Shand, 1997; Ikhimioya et al., 2005). Degradation constants *a, b* and *c* were derived using neway excel (version 5.0) as described by Chen (1997) and the accruing data was analyzed using SPSS (2003) and SAS (2002).

RESULTS AND DISCUSSION

Dry matter (DM) content increased by 72.98% (r^2 = 0.9341; $p < 0.0001$; SEM = 5.87) from 125.5 g DM at 6 to 217.1 g DM at 14 weeks, representing a gain of 1.6 g DM d^{-1} (table 1). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) increased by 33.05 ($p < 0.0001$), 62.64 ($P < 0.0001$) and 56.5% ($p < 0.0001$) respectively. Concentration of cellulose also increased ($p < 0.0001$). In contrast, crude protein (CP) and ether extract (EE) content and relative feed value (RFV) decreased by 66.67 ($r^2 = 0.9921$; $p < 0.0001$), 73.42 ($r^2 = 0.9419$; $p < 0.0001$) and 38.65% ($r^2 = 0.9927$; $p < 0.0001$) respectively. Concentration of hemicellulose, nitrogen free extract (NFE), non-structural carbohydrates (NSC) and total carbohydrates (CHO) exhibited inconsistent change pattern with advancing maturity of the grass. A high correlation (negative) was founded between age at harvest and CP ($r = - 0.994$; $p < 0.0001$), EE ($r = - 0.920$; $p < 0.0001$) and RFV ($r = - 0.930$; $p < 0.0001$)(table 1). The pattern of concentration change for hemicellulose, NFE and NSC were not correlated with advancing maturity of the grass. DM, OM, NDF, ADF, ADL and CHO recorded strong (positive) and significant correlation with age of the grass. From the results, it is also clear that quadratic function achieved a better fit for the prediction of the chemical nutrients' concentration change pattern over the study period as evidenced by the comparatively higher *p* - values and coefficients of determination (table 1). The chemical (table 1) values recorded are generally comparable to those reported for *Sorghum almum* (Kallah et al., 1999; Chin, 2002; Gohl, 1981) and other tropical grasses (Keftasa, 1990; Muia, 2000; Wouters, 1985; Snijders et al., 1992). At 10 weeks however, concentration of NDF surpassed the range of 600 – 650 g kg^{-1} DM suggested as the critical limit above which efficiency of utilization of tropical forages by ruminants would be impaired (Van Soest, 1982; Muia, 2000). At the same maturity stage, concentration of CP was at the threshold of the range of 70 – 80 g kg^{-1} DM below which intake of tropical feed resources would be severely depressed (Larbi et al., 1992; Minson, 1990; Leng, 1990). The observed increase in concentration of fibre components was consistent with Arthington and Brown (2005). The decline in protein concentration with advancing maturity of the grass was attributed to the decrease in CP concentration on leaf swards, stem and increased proportion of stem in the mature grass (Buxton, 1996). The recorded CP decline rate of 1.86 g kg^{-1} DM d^{-1} was slightly above the mean of 1 g kg^{-1} DM d^{-1} in data

reported by Minson (1990) for several tropical forages and falls within the 1.0 – 1.7 g kg^{-1} DM d^{-1} reported by Keftasa (1990) in Rhodes grass (*Chloris gayana*). Another important feature of the chemical composition of tropical grasses, which may in part account for their lower digestibility (Keftasa, 1990), is the relatively high content of phenolic compounds covalently bound in the cell wall (Lowry et al., 1993; Paul et al., 2003). In this study, presence of total phenolic compounds was recorded. The mean concentration however decreased by 25.25% between 6 and 14 weeks from 38.49 to 28.77 g kg^{-1} DM, which agreed with Martin (2006). These mean values fell within the range of 10 – 50 g kg^{-1} DM reported by Lowry et al. (1993) in 19 species of native and introduced grasses in North Queensland.

Dietary supply of rumen by-pass protein and microbial synthesis of free amino acids are recognized as the 2 main sources of amino acids available for absorption from the small intestine of ruminants under normal feeding conditions (Von Keyserlingk et al., 1998; Taghizadeh et al., 2005); hence the need to continue developing sufficient knowledge on amino acid profiles of important ruminant feedstuffs particularly forages. The amino acids concentration values obtained in this study (table 2) were consistent with those reported in literature (Tedeschi et al., 2001; Von Keyserlingk et al., 1998; Taghizadeh et al., 2005). Concentration of all amino acids assayed decreased with advancing maturity of the grass.

The study revealed that concentration of Arginine, Methionine, Lysine and total amino acids (TAA) in the grass herbage decreased by 66.02, 78.26, 46.44 and 63.41% respectively between 6 and 14 weeks (table 2). Decline in concentration of amino acids with advancing plant maturity has been recorded (Yao et al., 2000; Arthington and Brown, 2005). Leucine, Alanine, Aspartic acid and Glutamic acid showed the highest concentration, whereas Methionine, Serine and Cysteine recorded lowest concentration in *Sorghum almum* herbage. Rate of decrease in concentration of individual amino acids with age of the grass, differed markedly. Results further showed that rumen degradability of *Sorghum almum* herbage is strongly influenced by growth stage at harvest (tables 3, 4 and 5). This was evidenced by the observed marked differences in rumen degradability (table 3) and fermentation parametric (table 4) values between the various harvests. At 48 h incubation period, the DM and CP degradability of grass herbage harvested at the age of 6 weeks were 71.17 and 71.99%, whereas those of 14 weeks old herbage were 59.49 and 53.68% respectively.

Table 1. Chemical composition and relative feed value of *Sorghum almum* as influence by advancing maturity (g kg^{-1} DM except where stated).

	Age at harvest (Weeks)				**ANOVA**		**Contrasts**		**Correlation**	
Component	6	10	14	**SEM**	r^2	P^a	L	Q	*r*	P
Air DM (g kg^{-1})	125.5^a	153.9^b	217.1^c	5.87	0.9341	****	****	****	0.944	****
Analytical DM (g kg^{-1})	904.9^a	930.2^b	926.9^b	4.36	0.6885	**	*	**	0.663	*
Organic matter	753.1^a	781.7^b	803.5^c	5.48	0.8252	***	****	****	0.903	****
Crude protein	156.3^c	97.8^b	52.1^a	2.19	0.9921	****	****	****	-0.994	****
Crude fibre	195.8^a	346.3^b	356.6^b	6.72	0.9755	****	****	****	0.882	****
Neutral detergent Fibre	519.9^a	664.3^b	691.7^c	3.96	0.9918	****	****	****	0.957	****
Acid det. Fibre	259.6^a	377.6^b	422.2^c	5.89	0.9784	****	****	****	0.927	****
Acid det. Lignin	35.4^a	36.8^a	55.4^b	2.74	0.7881	***	**	***	0.794	**
Ether extract	39.5^c	16.5^b	10.5^a	1.79	0.9419	****	****	****	-0.920	****
Hemicellulose	260.4^a	286.5^b	269.5^a	4.91	0.6191	*	NS	*	0.271	NS
Cellulose	224.2^a	340.9^b	366.8^c	5.43	0.9775	****	****	****	0.928	****
N free extract [1]	361.5^b	321.1^a	384.3^b	7.11	0.8187	***	NS	****	0.322	NS
NSC [2]	132.5^b	72.9^a	122.4^b	3.79	0.9398	****	NS	****	-0.153	NS
CHO [3]	557.4^c	667.3^b	740.9^a	7.31	0.9731	****	****	****	0.980	****
RFV [4]	122.9^c	83.3^b	75.4^a	1.03	0.9927	****	****	****	-0.930	****

[1]**NFE** (g kg^{-1} DM) = DM – (EE + CP + Ash + CF) (Van Soest, 1982); [2]**NSC** was calculated as 100% - (CP% + NDF% + EE% +Ash%); [3]**CHO** was determined as as described by Arieli et al. (1999), where CHO (g kg^{-1} DM) = OM content – (CP + EE); [4]Relative feed value = [(88.9 – (0.78 x ADF%)) x (120/NDF%)]/ 1.29 (Agric-facts, 2006); ******** $p < 0.0001$; ******* $p < 0.001$; ****** $p < 0.01$; ***** $p < 0.5$ and **NS** – Not significant ($p > 0.05$); **L** – linear function; **Q** – quadratic function; $\mathbf{P^a}$ – ANOVA p-value; N =12 in all cases.

Table 2. Amino acid composition (mg g^{-1} DM) of *Sorghum almum* harvested at different maturity stages.

	Grass age (Weeks)			Regression equations				Correlation Coefficients[2]	
				Linear		Quadratic			
Amino Acid	6	10	14	r^2	P	r^2	P	*r*	P
Essential (mg/g DM)									
Arginine	5.15	2.65	1.75	0.901	**	0.968	**	- 0.949	**
Histidine	1.90	1.05	0.75	0.886	**	0.953	*	- 0.941	**
Isoleucine	4.11	2.05	1.41	0.890	**	0.970	**	- 0.944	**
Leucine	8.81	4.21	2.85	0.879	**	0.967	**	- 0.938	**
Lysine	4.50	3.05	2.41	0.929	**	0.974	**	- 0.964	**
Methionine	1.15	0.55	0.25	0.740	*	0.767	NS	- 0.860	*
Phenylalanine	5.91	3.05	1.65	0.898	**	0.933	*	- 0.948	**
Threonine	3.05	1.60	1.15	0.882	**	0.963	**	- 0.939	**
Valine	6.61	3.50	2.41	0.907	**	0.975	**	- 0.952	**
None essential (mg/g DM)									
Alanine	9.65	3.80	2.35	0.931	**	0.973	**	- 0.965	**
Aspartic acid[1]	8.35	5.80	3.65	0.950	***	0.952	*	- 0.975	***
Glutamic acid[1]	10.80	6.12	4.11	0.912	**	0.961	**	- 0.955	**
Glycine	5.30	2.55	1.82	0.871	**	0.968	**	- 0.934	**
Serine	1.15	0.65	0.51	0.792	*	0.869	*	- 0.890	*
Tyrosine	3.10	1.65	1.01	0.902	**	0.946	*	- 0.951	**
Proline	3.85	1.95	1.45	0.890	**	0.991	***	- 0.944	**
Cysteine	0.65	0.50	0.41	0.915	**	0.927	*	- 0.956	**
Total AA	81.31	44.55	29.75	0.912	**	0.967	**	- 0.955	**

1 – The Aspartic acid peak contained Asparagines, and the Glutamic acid peak contained Glutamine;
2 – Correlation between individual amino acid and advancing plant maturity.
******* $p < 0.001$; ****** $p < 0.01$; ***** $p < 0.5$ and **NS** – Not significant ($p > 0.05$);

Table 3. Influence of maturity on dry matter, organic matter and crude protein disappearance of *Sorghum almum.*

Incubation time (h)	N	Grass age (Weeks) 6	10	14	SEM	ANOVA P	r^2	CV
DM disappearance (%)								
0	12	28.18^{c}	25.31^{b}	21.69^{a}	0.865	***	0.6529	8.45
12	18	49.75^{c}	40.21^{b}	36.67^{a}	0.881	****	0.6985	8.86
24	18	59.15^{c}	51.51^{b}	46.21^{a}	0.935	****	0.6547	7.59
36	18	66.97^{c}	57.86^{b}	53.26^{a}	0.991	****	0.6604	7.08
48	18	71.17^{c}	65.22^{b}	59.49^{a}	0.609	****	0.7832	3.95
OM disappearance (%)								
0	12	12.95^{b}	11.07^{ab}	9.27^{a}	0.951	*	0.3327	20.98
12	18	39.18^{b}	29.69^{a}	27.55^{a}	0.955	****	0.6225	12.61
24	18	51.12^{c}	44.04^{b}	39.69^{a}	1.037	****	0.5484	9.78
36	18	60.19^{c}	51.97^{b}	47.99^{a}	0.968	****	0.6183	7.69
48	18	64.39^{c}	59.22^{b}	54.07^{a}	0.749	****	0.6506	5.36
CP disappearance (%)								
0	12	19.91^{b}	21.88^{b}	11.23^{a}	0.877	****	0.8476	12.16
12	18	47.23^{c}	36.45^{b}	26.88^{a}	0.844	****	0.8508	9.72
24	18	57.63^{c}	50.41^{b}	42.13^{a}	0.815	****	0.7801	6.91
36	18	67.34^{c}	57.44^{b}	51.59^{a}	0.828	****	0.7837	5.98
48	18	71.99^{c}	65.26^{b}	53.68^{a}	0.577	****	0.9101	3.84

N – Number of Nylon bags; **SEM** – Standard error mean; ***CV*** – Coefficient of variation;
Means with the same superscript ($^{a, b, c}$) within the same row are not significantly different ($p > 0.05$);
******** $p < 0.0001$; ******* $p < 0.001$; ***** $p < 0.5$

Organic matter degradability followed the same pattern. At the same incubation period, the quickly ('a'), slowly ('b'), rate of degradation ('c') and potential ('a + b') DM fermentation fractions of herbage harvested at 6 weeks were 13.63, 6.3, 48.08 and 8.74% respectively higher than those recorded for herbage harvested at 14 weeks (table 4). Similarly, the 'a', 'b', 'c' and 'a + b' CP fermentation fractions were 51.45, 9.95, 45.27 and 20.79% respectively higher for grass herbage harvested at 6 weeks than those recorded for herbage harvested at 14 weeks. The effective degradability (5%h^{-1}) of DM, OM and CP for herbage harvested at 6 weeks was 22.86, 21.30 and 32.51% respectively higher than those recorded for grass herbage harvested at 14 weeks (table 5). Effective degradability of DM, OM and CP decreased progressively with increasing rate of passage (table 5). ED of DM for grass herbage harvested at 6, 10 and 14 weeks decreased by 25.38, 32.41 and 34.4% respectively with an increase of rumen outflow rate from 2 to 8%h^{-1}.

Table 4. Fermentation characteristics of *Sorghum almum* as influence by age at harvest.

		Grass age (Weeks)				ANOVA		
Fraction	**N**	6	10	14	**SEM**	P	R^2	CV
Dry matter								
a	12	23.41^{c}	21.68^{b}	20.22^{a}	0.394	***	0.6862	4.43
b	18	46.99^{b}	47.46^{b}	44.02^{b}	0.937	*	0.3459	4.97
c	18	0.052^{b}	0.029^{a}	0.027^{a}	0.005	**	0.5364	32.45
a + b	18	70.39^{b}	69.14^{b}	64.24^{a}	1.041	**	0.5659	3.75
Organic matter								
a	12	13.13^{b}	10.99^{ab}	9.33^{a}	0.976	*	0.3363	21.43
b	18	57.68^{b}	54.09^{b}	44.54^{a}	1.262	****	0.7944	5.94
c	18	0.049^{b}	0.034^{a}	0.031^{a}	0.005	*	0.3319	32.69
a + b	18	70.82^{c}	65.09^{b}	53.87^{a}	1.431	****	0.8288	5.54
Crude protein								
a	12	21.69^{b}	19.19^{b}	10.53^{a}	0.709	****	0.8607	10.25
b	18	56.77^{b}	54.56^{b}	51.12^{a}	1.155	*	0.4473	5.22
c	18	0.055^{b}	0.033^{a}	0.029^{a}	0.004	***	0.6867	22.04
a + b	18	77.82^{b}	73.76^{b}	61.64^{a}	0.986	****	0.9015	3.34

N – Number of Nylon bags; **SEM** – Standard error mean; ***CV*** – Coefficient of variation;
Means with the same superscript ($^{a, b, c}$) within the same row are not significantly different ($p > 0.05$);
******** $p < 0.0001$; ******* $p < 0.001$; ****** $p < 0.01$; ***** $p < 0.5$

Table 5. Mean effective degradability values of nutrients in *Sorghum almum* as influenced by age at harvest.

Outflow		Grass age (Weeks)				ANOVA		Regression	
rate	**N**	6	10	14	**SEM**	r^2	P	L	Q
Dry matter									
k = 0.02	18	61.47^{c}	56.77^{b}	51.63^{a}	0.486	0.9715	****	****	****
k = 0.05	18	51.23^{c}	43.97^{b}	39.52^{a}	0.466	0.9817	****	****	****
k = 0.08	18	45.87^{c}	38.37^{b}	33.87^{a}	0.507	0.9795	****	****	****
Organic matter									
k = 0.02	18	53.31^{c}	48.81^{b}	44.37^{a}	0.573	0.9529	****	****	****
k = 0.05	18	41.13^{c}	35.13^{b}	32.37^{a}	0.481	0.9674	****	****	****
k = 0.08	18	34.63^{c}	28.57^{b}	25.64^{a}	0.501	0.9656	****	****	****
Crude protein									
k = 0.02	18	60.32^{c}	55.77^{b}	45.52^{a}	0.526	0.9857	****	****	****
k = 0.05	18	48.61^{c}	42.37^{b}	32.81^{a}	0.462	0.9899	****	****	****
k = 0.08	18	41.54^{c}	36.36^{b}	26.73^{a}	0.402	0.9915	****	****	****

N – Number of Nylon bags; **SEM** – Standard error mean; ***CV*** – Coefficient of variation;
Means with the same superscript ($^{a, b, c}$) within the same row are not significantly different $p > 0.05$);
k – Rumen outflow rate; **L** and **Q** – Linear and quadratic equations;
******** $p < 0.0001$

The obtained *in sacco* degradability and fermentation values in this study were consistent with those reported in literature for tropical grass (Keftasa, 1990; Muia, 2000; Rodriquez et al., 2005). A decline in rumen degradability of nutrients with advancing grass maturity has been recorded (Arthington and Brown, 2005; Mislevy and Martin, 1998; Bogoro et al., 2006; Rodriquez et al., 2005). Decrease of rumen fermentation parameters with advancing grass maturity and increased outflow rates has also been reported (Rodriquez et al., 2005; Ikhimioya et al., 2005). The observed variation in degradability between the different harvests could be due to the decreasing concentration of the more degradable cell contents (Van Soest, 1994) and the accumulation of lingo-cellulose fractions (Smith et al., 1989; Akin, 1989) compounded by the decreased leaf to stem ratio (Hides et al., 1983) as the grass matured. Lignified cells reduce the penetration of rumen fungal rhizoids (Latham et al., 1987), which results in reduced degradability. Though presence of total phenolics has been associated with decreased rumen degradability (Waghorn et al., 1994), no relationship between degradability and phenolic content was observed in this study.

CONCLUSION

Advancing maturity adversely affects the concentration of essential chemical nutrients, degradability and relative feed value of *Sorghum almum*. The results of this study favored between 6 and 10 weeks as the appropriate stage to feed *Sorghum almum* herbage. Caution should however be observed when feeding young because this study has shown that in immature herbage, concentration of phenolic compounds is high.

REFERENCES

Agyemang, K., D. L. Dogoo, and H. J. Makun. 1998. Profitability of forage production in smallholder peri-urban dairy production systems. Experimental Agriculture. 34: 423 – 437

Akin, D. E. 1989. Histological and physical factors affecting digestibility of forages. Agronomy Journal. 81: 17 – 25

Aminah, A., C. Abubakar and A. Izham 2000. Silages from tropical forages: Nutritional quality and milk production. In: Silage making in the tropics with particular emphasis on Smallholders. FAO. Plant production and protection paper No. 161

Arthington, J. D. and W. F. Brown. 2005. Estimation of feeding value of four tropical forage species at two stages of maturity. Journal Animal Science. 83: 1726 – 1731

Arieli, A., K. Shahar, S. J. Mabjeesh, S. Zamwel and D. Sklan. 1999. Estimation of the digestible energy of ruminant feedstuffs by the combined bag technique. Journal of Dairy Science. 82: 566 – 573

AGRIC – FACTS, 2006. Know your feed terms. Practical information for Alberta's agriculture industry, July, Alberta, Canada. pp 1 – 5

Association of Official Analytical Chemistry (AOAC), 1990. Official method of analyses 15th Ed. AOAC. Washngton, D.C. USA.

Abdulrazak, S. A. and T. Fujihara. 1999. Animal Nutrition: A Laboratory manual. Kashiwagi printing co. Japan. pp 32 – 39.

Bogdan, A. V. 1977. Tropical pasture and fodder plants. Longman, London.

Bogoro, S., D. J. U. Kallah and Gaiya. 2006. Effect of positioning of feed samples in two segments of the rumen on *in situ* degradability of feedstuffs. Pakistan Journal of Nutrition. 5: 152 – 155

Buxton, D. 1996. Quality related characteristics of forage as influenced by plant environment and agronomic factors. Animal Feed Science Technology. 59: 37 - 49

Catchpoole, V.F. 1972. Laboratory ensiling of *Sorghum almum* Cr. Crooble. Tropical grasslands. 6: 171 – 176.

Chen, X. B. 1997. Neway – Excel: A utility for processing data of feed degradability and *in Vitro* gas production. XBC laboratory. Rowett Research Institute. Aberdeen, AB2 9SB. UK.

Chin, F. Y. 2002. Ensilaging of tropical forages with particular reference to South East Asian Systems. Proceedings of the VIIIth International silage conference, 1 – 13th September 2002.

Duke, J.A. 1983: Handbook of legumes of world economic importance. Plenum Press, New York.

Goering, H. K. and P. J. van Soest. 1970. Forage fibre analysis. *In*: Agricultural handbook, No. 37. USDA, Washington, DC

Gohl, B. 1981. Tropical feeds. Feed information summaries and nutritive values. FAO Animal Production and Health Series 12. FAO, Rome.

Hides, D. I., Lovatt, J. A and Hayward, M. W. 1983. Influence of stage of maturity on the nutritive value of Italian ryegrasses. Grass Forage Science. 38: 38 - 38

Ikhimioya, I., O. A., Isa, U. J., Ikhatua and M. A. Bamikole. 2005. Rumen degradability of dry matter and crude protein in tree leaves and crop residues of humid Nigeria. Pakistan Journal of Nutrition 4: 313 - 320

Jaetzhold, R. and Schmidt, H. 1982. Farm management handbook of Kenya (Rift Valley). Ministry of Agriculture livestock development and marketing. Kenya.

Kallah, M. S., M. Baba, J. P. Alawa, I. R. Muhammad and R. J. Tanko. 1997. Ensiling quality of Columbus grass (*Sorghum almum*) growth in northern Nigeria. Animal Science and Technology. 68: 153 – 163.

Kallah, M.S.; I. R. Muhammad, M. Baba and R. Lawal. 1999: The effect of maturity on the composition of hay and silage made from Columbus grass (*Sorghum almum*). Tropical Grasslands. 33: 46 – 50.

Keftasa, D. 1990. Effect of management practices on Rhodes grass and Lucerne pastures with special references to developmental stages at cutting and associated changes in nutritional quality. Proceedings of the 1st Joint workshop held in Lilongwe Malawi, 5th – 8th Dec. 1988. In: B. H. Dzowela, A. D. Said, Asrat Wendem-Agenehu and J. A Kategile (Eds), Pasture Network for Eastern and Southern Africa.

Llames, C. R. and Fontaine, J. 1994. Determination of amino acid in feeds: Collaborative study. Journal of Association Official Analytical Chemistry International. 77: 1362 - 1402

Leng, R. A. 1990. Factors affecting the utilization of poor quality forages by ruminnts particularly under tropical conditions. Nutritional Research Reviews. 3: 277 – 303.

Larbi, A., J. Ochang, S. Grosse, T. Alemu and J. C. Harnadec. 1992. *Desmodium intortum* cv Green leaf and *Macrotyloma axillare* cv. Archer as dry season protein supplements for Jersey calves and milking cows in Ethiopia. Bulletin Health Production Africa. 40: 87 – 91

Latham, M. J., B. E. Brooker, G. L. Pettipher and P. J. Harris. 1978. *Ruminococcus flavefaciens* cell wall and adhesion to cotton cellulose and to cell walls in leaves to perennial rye grass (*Lolium perrene*). Applied Environmental Microbiology. 35: 156 – 165

Lowry, J. B., E. A. Sumpter, C. S. McSweeney, A. C. Schlink and B. Bowden. 1993. Phenolic acids in the fibre of some tropical grasses, effect on feed quality and their metabolism by sheep. Australian Journal of Agricultural Research. 44: 1123 – 1133

Myoya, T. J. and N. J. Mukurasi. 1987. A review of pasture and fodder crops germplasm evaluation at Uyale, Mbeya in Tanzania. In: African forage plant genetics resources, evaluation of forage germplasm and and extensive livestock production systems. Proceedings of the 3rd workshop, Arusha 27th – 30th April, 1987

Martin, A. K. 2006. Effect of stage of maturity of perennial rye grass on its content of some organic acids and phenolic compounds. Journal of the Science of Food and Agriculture. 21: 496 – 501

Minnesota department of natural resources. 1999. Minnesota and Federal prohibited and noxious plants by scientific name. Exotic species program. USA. pp 1 – 18.

Muhammad, I. R. 1993. Effect of planting date, nitrogen level and stage of maturity on yield and nutritive value of Columbus grass (*Sorghum almum*). M. Sc. Thesis. Ahmadu Bello University. Zaria, Nigeria

Muhammad, I. R., M. S. Kallah, R. J. Tanko, H. U. Ahmed and E. O. Otchere. 1994. *Sorghum almum* (Columbus grass): A potential fodder crop for sown pasture production in the semi-arid zones of Nigeria. 1st International conference on Research and Development in the arid zones of Nigeria, 19th – 25th June, 1994, CAZS, University of Maiduguri, Maiduguri, Nigeria.

Minson, D. J. 1990. Forage in ruminant nutrition. Academic press, Inc. San Diego. USA.

Muia, J. M. K. 2000. Use of Napier grass (*Pennisetum purpureum*) to improv smallholder milk production in Kenya. PhD. Thesis. Wageningen Agricultural University. The Netherlands

McDonald, I. 1981. A review model for estimation of protein degradability in the rumen. Journal of Agricultural Science Cambridge. 96: 251-252.

Mislevy, P., and F. G. Martin. 1998. Comparison of Tifton 85 and other Cynodon grasses for production and nutritive value under grazing. Soil Crop Science Society. FL Proceedings. 57:77–82.

Ørskov, E. R., F. D. Hovell and F. Mould. 1980. The use of nylon bag technique for the evaluation of feedstuffs. Tropical Animal Production. 5: 195 – 213.

Ørskov, E. R. and I. McDonald. 1979. The Estimation of protein degradability n the rumen from incubation measurements weighted according to rate of passage. Journal of Agricultural sciences, Cambridge. 92: 499 – 503.

Ørskov, E. R. and W. J. Shand. 1997. Use of the nylon bag technique for protein and energy evaluation and for rumen environment studies in ruminants. Livestock Research for Rural Development. 9 (1): http://www.cipav.org.co/lrrd/lrrd9/l/orskov.htm

Orodho, A. B. 2006: The role and importance of Napier grass in the smallholder dairy industry in Kenya. http://www.fao.org/ag/agp/agpc/doc/Newpub/napier/napier_kenya.htm

Palm, C. A. and A. P. Rowland. 1997. Minimum data set for characterization of plant quality for decomposition. In: (G. Candisch and K. E. Giller, Eds). Driven By Nature: Plant Litter Quality and Decomposition. CAB International, Wallingford, UK. pp 349 – 362

Paul, S. S., Kamra, D. N., Sastry, V. R. B., Sahu, N. P. and Kumar, A. 2003. Letters in Applied Microbiology. 38: 377 - 381

Reeds, C.F. 1976. Information summaries on 1000 economic plants. Typescripts submitted to the OSDA.

Rich, P. J., C. Grenier and G. Ejecta. 2004. Striga resistance in the wild relatives of Sorghum. Crop Science. 44: 2221 – 2229

Reed, J. D., B. A. Ramundo, L. E. Claflin and M. R. Tuinstra. 2002. Analysis of resistance to Ergot in Sorghum and Potential alternative hosts. Crop Science. 42: 1135 – 1138

Rodriquez, C. F. V. 2005. Nutritional evaluation and ruminal degradability of lines of forage Sorghum (*Sorghum sp*.). Agronomia Mesoamericana. 16: 215 – 223

Snijders, P. J. M., J. M. K. Muia and J. N. Kariuki. 1992. Yield and quality of Sweet potato vines harvested at different stages. Kenya Agricultural Research Institute (KARI), Naivasha. Kenya. (Unpub.). pp 3 – 9

Sheridan, K.P., Holland, J.F.; Thompson, J.A. and Hamilton, B.A. 2003. Growth rates of lambs and adult sheep grazing forage sorghums and Lucerne. Australian Journal of Experimental Agriculture and Animal Husbandry 12 (55): 144 – 145.

Smith, T., B. Manyuchi and S. Mikairi. 1989. Legume supplementation of maize stover. In: Utilization of research results on forage and agricultural py-product materials as animal feed resources in Africa (eds. B. H. Dzowela, A. N. Said, A. Wendem-Agenehu and J. A. Kategile). ILCA, Addis Ababa, Ethiopia pp. 303-320.

Statistical Analysis System (SAS). 2002. Guides for personal computers. Version 9.00. (Ed.) SAS Institute Inc., Cary, NC. USA.

SPSS (Stastistical Programs for Social Scientists). 2003. Apache software foundation. USA.

Tedeschi, L. O., A. N. Pell, D. G. Fox and C. R. Llames. 2001. The amino acid profiles of the whole plant and of four plant residues from temperate and tropical forages. Journal of Animal Science. 79: 525 – 532

Taghizadeh, A., M. D. Mesgaran, R. Valizadeh, F. E. Shahroodi and K. Stanford. 2005. Digestion of feed amino acids in the rumen and intestine of steers measured using a mobile nylon bag technique. Journal Dairy Science. 88: 1807 - 1814

Von Keyserlingk, M. A. G. Shelford, J. A. Puchala, R. Swift, M. L. and Fisher, L. J. 1998. *In situ*

Disappearance of Amino Acids from Grass Silage in the Rumen and Intestine of Cattle. Journal Dairy Science. 81: 140 – 149

Van Soest, P. J. and J. B. Robertson. 1985. Analysis of forages and fibrous foods. A Laboratory Manual for Animal Science. Report. 613. USA.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. Corvallis, 2nd Edition. Cornell University. Press. Ithaca, USA. pp 476

Van Soest, P. J. 1982. Nutritional Ecology of the ruminant. O & B books, Corvallis, Oregon, USA.

Wouters, A. P. 1985. Fodder production for zero-grazing. Proceeding of 2nd Symposium of animal production society of Kenya. 22nd November 1985. Ahiti, Kabete. Nairobi, Kenya. pp 1 – 17

Waterman, P. G. and S. Mole. 1994. Analysis of polyphenolics plant metabolites. Methods in Ecology. Blackwell Scientific publications, London, UK. pp 238

Waghorn, G. C., I. D. Shelton and W. C. McNabb. 1994. Effects of condensed tannins in *Lotus pedunculatus* on its nutritive value for sheep. 1. Non-nitrgenous aspects. Journal of Agricultural Science. Cambridge. 123: 99 – 107

Yao, J., B. Yan, X. Q. Wang and J. X. Liu. 2000. Nutritional evaluation of mulberry leaves as feed for ruminants. Livestock Research for Rural Development 12 (2) http://www.cipav.org.co/lrrd/lrrd12/2/yao122.htm

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