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REGULAR ARTICLES

Seasonal effect on rumen function in sheep on range in the Accra Plains of Ghana

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Abstract This study aimed at investigating the effect of the seasonal decline in quality and availability of feed on rumen function in sheep grazing without supplementation. Effects of season on rumen pH, ammonia nitrogen concentration and rumen degradation of urea-treated rice straw in grazing sheep were determined. Four fistulated Djallonké sheep were added to a group of grazing sheep and used for this study. Rumen contents were sampled for pH and ammonia in the rainy season and in the dry season. Ammoniated rice straw was incubated in the rumen to determine its degradation characteristics. Rumen pH was higher ($p<0.1$) in the dry season than in the rainy season. Rumen ammonia nitrogen concentrations on the other hand were similar ($p>0.05$) in the two seasons. *In sacco* dry matter degradation parameters of urea-ammoniated rice straw showed seasonal differences in the soluble (a) and the insoluble but degradable (b) fractions as well as lag time before the start of degradation. It was concluded that despite higher pH in the dry season and similar ammonia nitrogen concentration in the two seasons, rumen degradability of dry matter of urea-treated rice straw in sheep was higher in the rainy season than that in the dry season.

Keywords Season · Rumen · Ammonia · pH · Degradation · Grazing · Sheep

Introduction

As the season changes from wet to dry, fermentable carbohydrate levels in forages decline while fibre levels increase. Decreases in levels of fermentable carbohydrates will reduce the amount of volatile fatty acids produced in the rumen and thus cause an increase in ruminal pH during the dry season. Also, increased chewing and rumination times associated with increased fibre content of feed result in increased amount of saliva production (Wang et al. 2010), hence increase in the buffering capacity of the rumen content. Thus, changes in fibre and fermentable carbohydrate levels will be expected to cause some changes in rumen pH and consequently activity of cellulolytic bacteria.

Ammonia production in the rumen is another important abiotic factor affecting feed degradation in the rumen. Several rumen cellulolytic bacteria such as *Ruminococcus albus* utilise ammonia as their preferred source of nitrogen (Kim et al. 2014). Rumen microbial growth is therefore dependent on availability of ammonia nitrogen in the rumen (Brooks et al. 2012). Rumen ammonia level is therefore necessary for the efficient utilisation of fibrous feeds and may give an indication of dietary nitrogen adequacy.

Seasonal changes in rumen pH and ammonia nitrogen concentration will therefore affect fibre degradation in the rumen and consequently degradation of fibrous feeds such as rice straw. This study was thus designed to determine the effect of season on rumen pH, ammonia nitrogen concentration and rumen degradation of low quality forage in grazing sheep.

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Materials and methods

Location

The study was conducted at the Livestock and Poultry Research Centre (LIPREC) of the University of Ghana (5° 68′ N, 0° 10′ W) in the Coastal Savannah belt of Ghana, West Africa. Annual rainfall averages 881 mm per annum but with a high degree of variability. The rainfall pattern of the study area is shown in Fig. 1. The rainy season was from April to June, the minor season was from September to October, and the dry season from November to March.

Animals

Animals for this study were a group of Djallonké sheep weighing averagely 21.2±2.2 kg and aged between 10 and 12 months. Ten of the sheep were intact females that were added to four fistulated wethers to form a grazing group. Fistulation was done following the Standard Operating Procedures for the fistulation of the gastrointestinal tract as outlined by the Department of Primary Industries of New South Wales Government, Australia (NSW Government 2012). They were fitted with rumen cannulae that were a modified version of one described by Elices et al. (2010). The sheep were grazed between the hours of 0830 and 1430 h. Animals were given routine prophylactic treatments. They passed through foot baths regularly in the morning, were dewormed every 2 months with albendazole-based dewormers and were dipped once in 2 weeks using avomectin.

Sample collection

A period of 2 weeks was allowed for the animals to adjust to the grazing area and the diet. This was followed by a data collection period of 1 week. Rumen content was sampled through the cannulae from each of the four fistulated sheep which served as replicates. Samples were taken before feeding (0 h) and at 2, 4, 6 and 8 h after start of grazing. Sampling was done in January and repeated in February to represent the dry season. The entire procedure was repeated in June and July to represent the rainy season. The rumen fluid was obtained by straining the rumen content through four layers of cheese cloth.

Determination of rumen pH and ammonia nitrogen concentration

Rumen pH was determined immediately after straining the fluid using a potable pH meter. Rumen fluid for ammonia

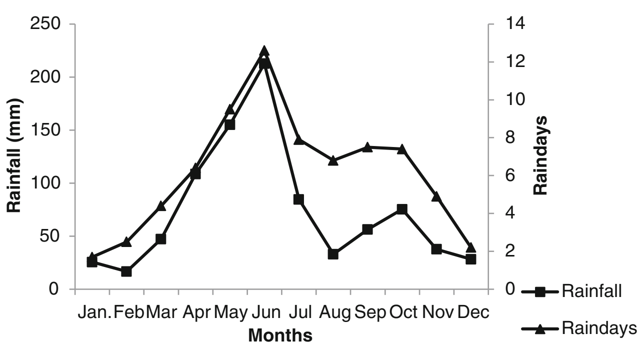

Fig. 1 Ten-year mean rainfall pattern at the study site

determination was acidified (about 20 ml preserved with two drops of 10 N H_2SO_4) and stored frozen pending ammonia analysis. Ammonia nitrogen in rumen fluid was determined by spectrophotometry using the indophenol method originally described by Chaney and Marbach (1962) and validated by Souza et al. (2013).

Determination of degradation of standard feed in the rumen

Ammoniated rice straw was ground through 1.0-mm screen and weighed into Dacron bags. These were incubated in the rumen of sheep for 3, 6, 12, 24, 48, 72 and 96 h. Kinetics of dry matter degradation were quantitated by fitting percent disappearance (P) to time (T) in hours, following the first-order kinetic model proposed by Ørskov and McDonald (1979) in an iterative least squares procedure as

$$P = a + b(1 - \exp^{-ct}) \qquad \text{(model1)}$$

and potential degradability (PD) of dry matter calculated as

$$\mathrm{PD} = a + b \qquad \text{(model2)}$$

where P is dry matter disappearance from the bags, a is the soluble fraction, b is the insoluble but potentially degradable fraction, c is the fractional rate of degradation of b and t is the period of incubation in hours.

Effective degradation (ED) of dry matter in the rumen was determined using assumed rumen fractional outflow rates of 0.02 and 0.03. ED of dry matter of the standard feed was then calculated as

$$\mathrm{ED} = a + [(b \times c)/(\mathrm{c} + k)]$$

where a, b and c are the constants as in model 1 and k is fractional outflow rate.

Lag time (t_0) before the start of degradation was calculated as

$$t_0 = (1/\mathrm{c}) \log[\mathrm{b} / (\mathrm{a} + \mathrm{b} - P_0] \qquad \text{(model3)}$$

where P_0 is degradation at zero incubation time, i.e. wash value and a, b and c are as in models 1 and 2.

Wash value was determined by immersing two Dacron bags containing feed samples in water kept at 39 °C. After 1 h, the bags were removed, washed and dried just as those that were incubated in the rumen. The weight loss due to this process was taken as the wash value, which represents the amount of dry matter loss due to dissolution in water.

Time lag, t_0, was then used to modify model 1 according to Hackman et al. (2008) as

$$P = a + b\left(1 - \exp^{-c(t - t)_0}\right) \quad \text{(model4)}$$

Model 4 was then used to plot the degradation pattern of treated rice straw.

Chemical analysis

Urea ammoniated and untreated rice straw samples were analysed for dry matter, crude protein and organic matter according to AOAC (1990) and for detergent fibre and components of fibre according to Goering and Van Soest (1970) (Table 1).

Statistical analysis

Data on rumen ammonia nitrogen, rumen content and degradation parameters were analysed as split-plot designs with season as the main plot and months within season as subplots. Where there were significant differences, monthly means were separated using the least significant difference method.

Results

Forages present in the study area are listed in Table 2. Apart from *Chamaecrista rotundifolia* which was not available during most parts of the dry season, all the other species were available for sheep to select throughout the period of observation.

Rumen pH and ammonia nitrogen concentration

Rumen pH values ranged between 7.1 and 5.4 (Fig. 2). Minimum pH levels were between 2 and 4 h after the commencement of feeding. The seasonal differences in pH widened after 2 h from the start of feeding. Generally, mean rumen pH values were lower ($p<0.01$) in the rainy season than those in the dry season (Table 3).

Mean rumen ammonia nitrogen concentration observed in this study ranged between 10.2 mg/dl in June and 11.0 mg/dl in July (Table 3). The ammonia concentration in July was higher ($p<0.01$) than in June but similar ($p>0.05$) to those observed in January and February. There was no clear seasonal trend in mean ammonia nitrogen concentrations. Values observed were similar ($p>0.05$) in both seasons. The patterns of rumen ammonia nitrogen concentration observed are presented in Fig. 3. Maximum ammonia concentrations occurred at different times after feeding. In the rainy season months of June and July, the maximum ammonia nitrogen concentration occurred 6 h after feeding, but during the dry season months of January and February, the maximum concentration occurred 4 h after the start of feeding.

Table 1 Chemical composition of untreated and urea-ammoniated rice straw

Fraction	Concentration (g/kg)	
	Untreated rice straw	Ammoniated rice straw
Dry matter	91.8	90.0
Organic matter	78.3	73.8
Crude protein	5.2	9.3
Neutral detergent fibre	69.7	60.2
Acid detergent fibre	51.4	49.1
Cellulose	42.9	38.8
Hemicellulose	18.4	10.4
Lignin	8.5	9.0
Ash	13.5	15.4

In sacco degradation of a standard low-quality forage

The patterns of degradation based on estimated parameters are shown in Fig. 4. There were differences between the dry season and the rainy season with respect to the degree of disappearance of dry matter from the initial stages of the degradation process. However, by 96 h, values of disappearance of dry matter were similar between the rainy and dry seasons.

Dry matter degradation parameters of urea-ammoniated rice straw are presented in Table 4. The estimated soluble fraction (*a*) was higher ($p<0.01$) in the rainy season than in the dry season. The insoluble but degradable fraction, on the other hand, was higher $p<0.05$ in the dry season than in the dry season. Also, the potentially degradable fraction ($a+b$) was higher ($p<0.05$) in the

Table 2 Forage species identified at the study site

Grasses and forbs	Browses
Brachiaria decumbens	*Grewia carpinifolia*
Digitaria horisontalis	*Securinega virosa*
Chamaecrista rotundifolia	*Millettia thonningii*
Tephrosia vogelii	*Pithecellobium dulce*[a]
Stylosanthes guianensis	*Prosopis juliflora*
Sporobolus pyramidalis *Mimosa pudica*	*Leucaena leucocephala*[a]
Commelina vogelli	
Vetiveria fulvibarbis	

[a] Species present but not selected because they were out of reach of the sheep

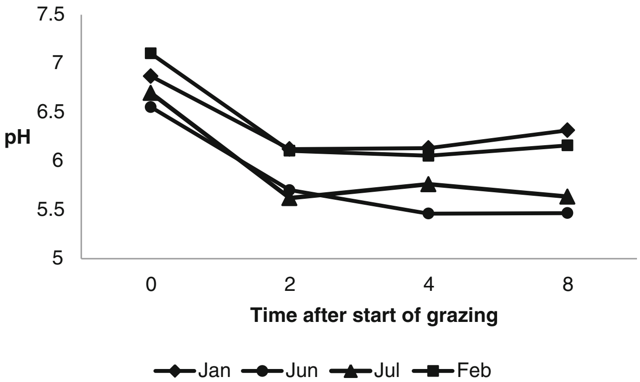

Fig. 2 Effect of season on rumen pH of grazing sheep (Jan. and Feb., dry season; Jun. and Jul., rainy season)

dry season than in the rainy season. Fractional rate of degradation of treated straw dry matter was higher in July than that in the dry season months of January and February. However, the value for June was similar ($p>0.05$) to the dry season values. Overall, degradation rate was higher in the rainy season than in the dry season. ED was influenced ($p<0.01$) by season at both values of k. The means for the dry and rainy seasons were 55.8 and 64.4 %, respectively, when $k=0.02$ and 49.5 and 59.9 %, respectively, when $k=0.03$. Time lag before the start of degradation (t_0) was also influenced by season. Time lag was higher ($p<0.01$) for the dry season months of January and February than for the rainy season months. However, within each season, t_0 values were similar ($p>0.05$).

Discussions

Rumen pH

The ranges of pH observed in this study were within the limits reported in the literature (Grimaud et al. 1999; Estrada et al. 2010). Increased rumen pH with advancing season has also been reported in earlier studies (Estrada et al. 2010). Lower pH values observed in the rainy season may be due to higher levels of fermentable carbohydrates in the forages selected during the rainy season. It may also be attributable to increased dry matter intake during the rainy season. Williams

Table 3 Effect of season on mean rumen pH and ammonia nitrogen concentration

Parameter	Dry season		Rainy season	
	Jan	Feb	Jun	Jul
Rumen pH	6.4 b	6.4 b	5.8 a	5.9 a
NH_3-N (mg/dl)	10.6 ab	10.5 a	11.0 b	10.2 a

Figures in a row with different letters are significantly different ($p<0.05$)

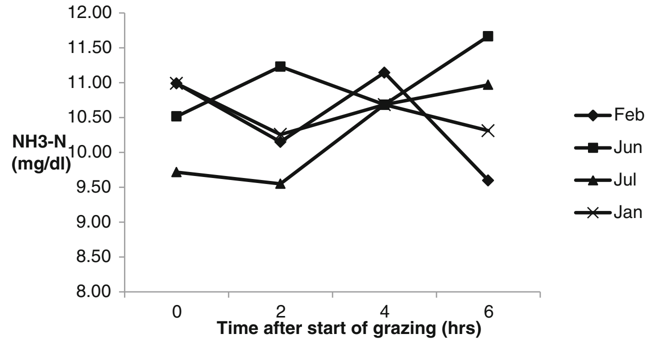

Fig. 3 Effect of season on rumen ammonia concentration (Jan. and Feb., dry season; Jun. and Jul., rainy season)

et al. (2005) demonstrated that rumen fluid pH decreased linearly with pasture intake in cows on pasture of similar quality. Increased pH during periods of underfeeding has also been reported (Grimaud et al. 1999). Higher fibre content of forages consumed during the dry season may also be important in increasing rumen pH. Increased fibre in feed leads to increased chewing and rumination which in turn result in higher saliva production (Wang et al. 2010, thus improving the buffering capacity of the rumen fluid. Depression in rumen pH is known to decrease fibre digestion in the rumen (Sung et al. 2007; Dijkstra et al. 2012). Higher pH during the dry season may thus favour degradation of fibrous feed.

Rumen ammonia nitrogen concentration

Levels of rumen ammonia observed in the current study were within the range given in the literature. Most studies have reported ammonia concentration in sheep of between 1 and 14 mg/dl (Miller and Thompson 2003; Horadogado et al. 2008; Lascano and Heinrichs 2009). However, some others have reported much higher levels (Kaur et al. 2008). The mean

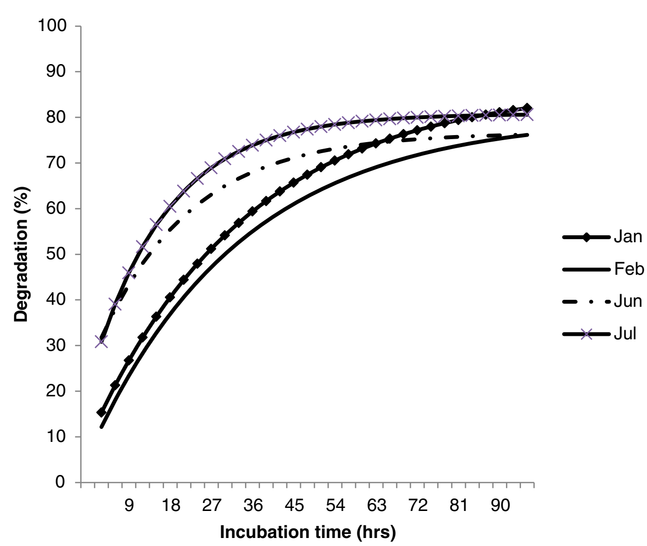

Fig. 4 Effect of season on *in sacco* degradation pattern of ammoniated rice straw

Table 4 Seasonal effect of degradation parameters for ammoniated rice straw (% of DM)

Parameter	Dry season		Rainy season	
	Jan	Feb	Jun	Jul
a	18.2 a	15.5 a	27.6 b	25.6 b
b	68.7 b	64.8 b	49.0 a	55.2 a
C (h^{-1})	0.03 a	0.03 a	0.05 ab	0.06 b
PD (*a*+*b*)	86.9 b	80.4 ab	76.6 a	80.8 a
ED (*k*=0.02)	56.4	55.2	62.5	66.3
ED (*k*=0.03)	50.3 a	48.8 a	58.1 b	61.7 b
t_0 (h)	18.2 a	15.5 a	27.6 b	25.6 b

Figures in a row bearing different letters are significantly different ($p<0.05$)

a soluble fraction, *b* insoluble but potentially degradable fraction, *c* fractional rate of degradation, *PD* potential degradability, *Ed* effective degradation, t_0 time lag before the start of degradation

ammonia concentration of 11.02 mg/dl observed during the rainy season in this study is similar to that of 11.5 mg/dl reported by Estrada et al. (2010) for steers grazing during the rainy season in Mexico. However, the dry season level was much higher in the current study (10.51 vs 4.70 mg/dl). Relatively high rumen ammonia concentration during the dry season may be a result of the large variety of species available to the sheep in the current study. Availability of browses, especially, may have allowed for dietary shifts that helped minimise changes in the quality of the diet selected.

Decreased rumen ammonia from the rainy season (June) to the dry season (January and February) may be a result of decreased nitrogen intake. Increases in rumen ammonia concentration associated with increased forage nitrogen levels and, consequently, increased nitrogen intake have been reported (Estrada et al. 2010; Ribeiro Filho et al. 2012). However, rumen ammonia nitrogen levels during the dry season were within the range of 3.5 to 25 mg/dl, considered optimum for efficient microbial growth in the rumen (Pengpeng and Tan 2013).

In sacco degradation of a standard low-quality forage

Degradation rates of 0.029 and 0.030 observed during the dry season were within the range of 0.025 to 0.035 reported for treated rice straw in sheep on low-quality diets (Orden et al. 2000; Fadel Elseed et al. 2003). The higher degradation rates observed during the dry season are attributable to both the quality of feed selected and the level of feeding. Lower dry matter digestibility during periods of underfeeding has been reported (Atti et al. 2004). Considering that degradation rates correlate positively with dry matter intake (Martins et al. 2013), the higher degradation rate observed in the rainy season is expected to enhance feed intake and thus improve animal performance.

Values for time lag before the start of degradation observed in the dry season (4.40 and 4.69 h) were similar to those estimated by Soebarinoto et al. (1997) which ranged between 4.51 and 5.68 h for ammoniated straw incubated in sheep fed barley straw. Decreased lag time during the rainy season is attributable to improved rumen environment which led to higher rate of colonisation of substrate by rumen microbes, hence earlier initiation of the degradation process. Microbial attachment and colonisation have been shown to be necessary steps in the degradation of fibrous feed (Sung et al. 2007) and are influenced by availability of readily available carbohydrates among other factors (Miron et al. 2001).

Conclusions

Rumen degradability of dry matter of urea-treated rice straw in sheep was higher during the rainy season despite higher pH in the dry season and similar ammonia nitrogen concentration in the two seasons.

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Conflict of interest The authors declare that they have no conflict of interest whatsoever. This study did not involve any commercial entity in terms of funding or the conduct of the study.

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