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THE EFFECTS OF MOISTURE, UREA LEVEL AND METHOD OF APPLICATION ON THE CHEMICAL COMPOSITION AND DIGESTIBILITY OF NATIVE GRASS HAY IN THE CARIBBEAN

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ABSTRACT

Ruminant livestock production in the Caribbean is severely hampered by seasonal deficiencies in the quality and quantity of forage and recurrent body weight losses. A series of experiments were conducted on St. Croix to evaluate the use of urea-ammoniation for improving the quality of locally produced guineagrass (*Panicum maximum*) hay. Initially, 5-kg samples of hay were reconstituted to 25 or 40% final moisture concentration and treated with urea at 0, 4, 6 or 8% of forage dry matter (DM), with or without urease addition. Urease application had no influence ($P > 0.10$) on any forage quality measure and there were no interactions between urease and moisture or urea treatments. However, increasing urea treatment level resulted in linear ($P = 0.0001$) increases in crude protein (CP) (4.2 to 18.4%) and in vitro organic matter digestion (IVOMD) (30.7 to 42.0%) of the hay. The quality improvement was greater at the 25% than at the 40% moisture concentrations. Subsequently, round bales (322 $\pm$ 25 kg) of guineagrass hay were reconstituted to 25 or 40% final moisture concentration and treated with urea (0, 4 or 6% of forage DM) by either spraying the urea solution on both flat surfaces of bales or by low pressure (10 psi) injection at five sites on each flat surface. Urea treatment increased CP and IVOMD when the urea solution was sprayed-on rather than injected into bales. Neutral detergent fiber (NDF) concentration in hay was also reduced (74.3 to 72.5%) when solution was sprayed onto the hay. A lower ammoniation effectiveness was observed at the 40% moisture concentration because of greater urea seepage losses. From these preliminary results, diets based on 25% moisture, sprayed-on, urea treated hay described above, were selected for sheep feeding trial.

INTRODUCTION

Pastures in the Caribbean Basin provide forage that is frequently deficient in both quantity and quality during the dry season resulting in reduced animal performance. Additionally, in the rainy season, when grasses are growing, energy and protein content of forage decline rapidly with maturity and low quality forage accumulates. Usually, harvesting of forage for hay is delayed in order to obtain high yields. This leads to low quality hay production in the region. The inability of native pastures to produce quality forage during cyclic dry periods was clearly demonstrated by Oakes (1969). Crude protein content of three predominant grasses in the dry season were 4.6, 3.5 and 3.4% for guineagrass, pangola grass (*Digitaria decumbens*) and hurricane grass (*Bothriochloa pertusa*), respectively. The seasonal CP content of guineagrass varied from 4.2 to 6.5% in response to a change of harvesting interval from 6 to 2 months (Oakes, 1966). A CP content of 8.13% was obtained for a fertilized guineagrass pasture at the sheep facility of the University of the Virgin

Islands (Wildeus, 1988). Crude protein content lower than 8% is known to limit forage intake and animal performance (Minson and Milford, 1967). In a 1989 survey, Boateng (personal communication) also found that hay produced on St. Croix was low in CP concentration (5.2 to 6.5%) and total digestible nutrients (51 to 59%). The poor feeding value of hay necessitated the use of dairy rations that contained more than 60% DM from imported concentrates at a monthly estimated cost of $24,500 to the three major dairies in St. Croix during the severe 1989-90 dry season. In a protein supplementation trial on St. Croix, the native guineagrass basal diet had an average CP content of 6.3% and IVOMD of 36% (Hammond and Wildeus, 1991). Five of the eight lambs on the basal diet had to be removed in the course of the 63 d trial because of severe weight losses. The remaining 'Control' lambs lost an average 56 g daily compared with an average 133 g daily gain by lambs fed the basal diet supplemented with an *ad libitum* supply of coconut meal. Since ruminants are in constant competition with monogastric animals for the supply of coconut meal in the region, alternative feed sources must be developed.

Chemical treatment of forage as a method of improving nutritive value of mature forages has been widely investigated (Tarkow and Feist, 1969; Oji et al., 1977, Klopfenstein, 1978; Brown et al., 1987; Brown, 1988). Among the chemicals used, ammonia (NH_3), in either the aqueous or anhydrous form, has received considerable attention because of its dual capability to increase crude protein content and fiber digestibility. Improvement in fiber digestibility is brought about by partial solubilization of hemicellulose, lignin and silica and the hydrolysis of uronic and acetic acid esters (Klopfenstein, 1978; Chesson et al., 1983; Sundstol, 1988). A disruption of intermolecular hydrogen bonding in cellulose is also implicated. However, the use of feed grade urea for ammoniation has greater application in the tropics where ammonia gas is largely unavailable and where farmers lack the necessary equipment to handle this unpleasant, dangerous gas. Urea treatment relies on the hydrolysis of urea to ammonia via microbial and/or plant ureases present on/in forage (Tetlow, 1983; Williams et al., 1984).

Improving the feeding value of conserved forage by ammoniation will aid in sustaining livestock production during the dry season. Most urea treatment research has been conducted with wilted or reconstituted cereal straw stored by ensiling. Little information is available concerning ureatreatment of tropical grass hay. Baseline information on levels of moisture and urea treatment and storage methods for tropical forages in the Caribbean and their influence on animal performance should be determined.

The objective of the initial experiments was to determine the effects of urea application method, final forage moisture and urea-treatment levels, and urease addition on the chemical composition and in vitro organic matter digestion (IVOMD) of guineagrass hay.

MATERIALS AND METHODS

Experiment 1. Influence of moisture concentration, urea level and urease addition on the quality of guineagrass hay.

Five-kg samples of native guineagrass hay were weighed. Based on the DM content of the hay, urea was weighed and dissolved in sufficient weight of water to reconstitute final forage moisture to either 25 or 40%, at 0, 4, 6 or 8% DM urea treatment levels. Urea solutions were thoroughly mixed with forage. Powdered urease was added in the ratio of 1:400 g of urea to half of the treated samples. Each moisture concentration (2) x urea level (4) x urease (2) factorial treatment was applied to 3 replicate samples. Treated forage was stored at ambient temperature (approximately 25 °C) in sealed, 6 mil plastic bags for 60 d. Dried, ground, initial and urea-ammoniated subsamples were analyzed for CP (Gallaher et al., 1975), cell wall components (Goering and Van Soest, 1970) and IVOMD (Moore and Mott, 1974). Data were analyzed as a completely randomized design according to the GLM procedure of SAS (1988). Model sums of squares were partitioned into main effects of forage moisture, urease addition, linear and quadratic effects of urea treatment level, and two-way and three-way interactions between main effects.

Experiment 2A. Influence of moisture concentration, urea level and application method on the feeding value of bales of mature native grass hay.

Round bales of known botanical composition were procured from the local Department of Agriculture on St. Croix. Core subsamples of hay were drilled out of the bales for DM determination. Bales were weighed separately. Urea solutions were prepared as described in Experiment 1 to reconstitute bale final moisture concentration to 25 or 40% at urea-treatment levels of 0, 4 or 6% of forage DM. Solution was applied either by spraying half of it on each flat surface of bale or by low pressure (10 psi) injection at five sites on each flat surface. Each factorial (3 x 2 x 2) treatment was applied to 4 round bales. Treated bales were immediately enclosed in separate 6 mil plastic bags and stored in the field for 60 d. Core subsamples were drilled from urea-ammoniated bales, dried and ground. Initial and final ground subsamples were subjected to similar quality analyses as described in Experiment 1. Data were analyzed as completely randomized design. Model sums of squares were partitioned into main effects of application method, forage moisture, linear and quadratic effects of urea treatment level, and two-way and three-way interactions between main effects.

Experiment 2B

A concurrent trial was conducted in which urea levels in bales of hay were confounded with moisture application by using a common (15%) urea solution to achieve urea treatment levels (4 and 6% DM). Each method of application (sprayed-on vs. injected) by urea level (0, 4 or 6%) factorial (2 x 3) treatment was applied to 4 bales of hay. Model sums of squares were partitioned into main effects of application method, linear and quadratic effects of urea treatment level and two-way interaction between main effects.

RESULTS AND DISCUSSION

Experiment 1

Urease treatment had no influence on CP ($P = 0.14$) or on any other forage quality measure ($P > 0.57$) and there were no interactions ($P > 0.10$) between urease and other treatment variables (Table 1). The fact that quality of guineagrass hay was unaffected by urease addition has an important practical implication in the use of urea-ammoniation. Urease is an expensive item and would adversely offset the cost/benefit ratio of the treatment. However, increasing urea treatment level from 0 to 8% of DM resulted in a curvilinear increase in CP (4.3 to 18.4%) and a linear increase in IVOMD (30.7 to 42.0%). The improvement in forage CP due to urea treatment was greater at the 25% than the 40% moisture levels. Reduction in NDF due to urea-ammoniation was minor ($P = 0.13$), probably due to the lower NDF of untreated hay (75.5%) compared to that seen in some other tropical forages (Brown, 1988). Increasing urea level also lowered ($P = 0.03$) the acid detergent lignin (ADL) content in the hay at the 40% moisture treatment level (Table 1).

Experiment 2A

Average forage botanical composition of the native pasture that was cut for hay was approximately 87% DM of guineagrass, 5% leucaena (*Leucaena leucocephala*) stems, 4% johnson grass (*Sorghum halepense*), 2% casha (*Acacia* spp.) stems, 1% hurricane grass and 1% other legumes. The average round bale weighed 322 $\pm$ 25 kg with an initial DM content of 88.4%.

Crude protein, NDF and IVOMD of the untreated bales of hay averaged 5.4%, 73.7% and 41.7%, respectively. An application method x urea treatment interaction existed for CP ($P = 0.0001$), NDF

(P = 0.05) and ADL (P = 0.02) (Table 2). Urea treatment level increased CP and IVOMD when the urea solution was sprayed-on rather than injected into the bales. The NDF concentration was also reduced (74.3 to 72.5) when urea solution was sprayed onto the hay, although the absolute reduction was minor. The lower ammoniation effectiveness from urea injection was probably due to the urea solution becoming localized in the bales, in contrast to the uniform distribution from the sprayed-on treatment. Additionally, an application method x moisture x urea treatment interaction (P < 0.05) was observed for CP (Table 2). Approximately 64 kg or 164 kg of water was requiredto reconstitute a bale of hay to either 25% or 40% moisture concentrations, respectively. Substantial seepage of urea solution from bales was observed at the 40% moisture concentration, leading to a generally lower effective urea treatment level at the higher moisture concentration, even for the sprayed-on treatment.

Experiment 2B

In the concurrent experiment, approximately 75 kg (64 kg water) and 112 kg (95 kg water) of the 15% urea solution were applied to a bale of hay to achieve 4% and 6% urea treatment levels, respectively. With the average bale weight and DM content at 322 kg and 88%, respectively, final moisture concentration for treated bales were approximately 26% and 31% for the 4 and 6% urea treatment levels, respectively. Therefore, using the 15% strength urea solution to achieve the selected urea levels produced intermediate effects on forage quality of hay (Table 3) as described above for the 25% and 40% moisture levels. With increasing urea treatment level from the 15% urea solution, CP content of hay was improved from 5.4 to 8.2 and IVOMD from 42 to 48% for the sprayed-on, but not for the injected treatments (Table 3). The NDF and hemicellulose (HC) levels also decreased with increasing urea level for the sprayed-on treatment (Table 3).

CONCLUSIONS

Crude protein content in bales of guineagrass hay was doubled (5.0 to 10.0%) and IVOMD was improved (43 to 49%) from sprayed-on urea-ammoniation (0 to 6% of forage DM) at the 25% final moisture concentration, without urease application. For guineagrass hay with over 88% DM, raising the moisture level to 40% would lead to considerable seepage and urea losses, and therefore, reduced effective ammoniation. The use of appropriate urea solution strength to restrict reconstituted hay moisture concentration between 25% and 30% is recommended. Subsequent to these preliminary results, inexpensive diets based on urea-treated hay were formulated for sheep feeding trial.

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Table 1. The effects of urease addition, moisture and urea treatment levels on the chemical composition and in vitro digestion of guineagrass hay in Experiment 1.

Urease	Moisture	Urea	CP	NDF	ADF	HC	Cellulose	ADL	IVOMD
	%								
Without	25	0	4.2	77.0	49.6	39.7	27.4	9.9	31.9
		4	11.9	76.5	48.2	38.9	28.2	9.3	39.9
		6	15.5	74.1	47.8	37.7	26.3	10.0	39.2
		8	17.7	74.4	46.7	37.0	27.7	9.7	39.1
	40	0	3.9	74.9	48.6	38.1	26.2	10.5	31.7
		4	9.7	76.5	50.0	38.6	26.4	11.5	41.1
		6	12.7	73.7	47.4	37.7	26.0	10.0	45.7
		8	15.9	73.9	47.0	37.3	26.9	9.7	42.7
With	25	0	4.2	76.5	49.9	38.8	26.6	11.1	29.5
		4	11.6	74.3	45.6	36.5	28.6	9.2	41.0
		6	14.3	77.8	50.3	39.7	27.5	10.6	38.9
		8	21.0	74.1	47.5	37.7	26.6	9.7	39.6
	40	0	4.8	73.7	47.3	36.3	26.4	10.9	29.7
		4	8.7	76.0	50.5	39.7	25.5	10.8	33.3
		6	12.7	73.4	46.9	38.0	26.6	8.8	43.0
		8	19.0	73.2	46.4	37.7	26.8	8.8	46.4
SE			0.79	0.37	0.39	0.35	0.24	0.19	1.06

Probability values

Moisture (M)	0.0001	0.13	0.85	0.05	0.66	0.62	0.38
Urease	0.14	0.75	0.84	0.87	0.94	0.76	0.57
Urea (U)	0.0001	0.13	0.10	0.78	0.51	0.03	0.0001
Ureasq	0.03	0.27	0.38	0.80	0.44	0.73	0.16
M x U	0.04	0.60	0.77	0.73	0.39	0.26	0.16

Table 2. The effects of method of application, moisture and urea treatment levels on the chemical composition and in vitro digestion of guineagrass hay in Experiment 2A.

Method of application	Moisture	Urea	CP	NDF	ADF	Cellu lose	HC	ADL	IVOMD
			g kg^{-1}						
Spray	25	0	5.3	74.6	45.5	37.3	29.1	8.1	42.6
		4	7.8	74.0	45.3	37.5	28.8	7.8	48.2
		6	10.5	72.6	44.6	36.4	28.0	8.2	49.3
	40	0	5.9	73.9	45.0	36.6	28.9	8.4	42.4
		4	6.8	74.9	46.0	38.0	28.9	7.9	45.9
		6	8.1	72.3	43.1	35.8	29.1	7.4	48.2
Inject	25	0	5.3	72.9	43.4	36.2	29.5	7.2	42.0
		4	6.7	73.4	45.0	37.5	28.4	7.5	44.0
		6	6.8	73.9	45.4	37.6	28.6	7.8	43.5
	40	0	5.7	73.5	42.5	35.9	31.0	6.6	43.8
		4	5.7	74.7	44.7	37.4	30.0	7.3	44.3
		6	6.4	74.3	43.5	35.8	30.8	7.3	46.7
SE			2.2	2.5	3.4	2.7	2.5	1.2	5.8

Probability values

Application (A)	0.0001	0.88	0.24	0.70	0.08	0.008	0.06
Moisture (M)	0.003	0.48	0.31	0.40	0.04	0.27	0.78
Urea (U)	0.0001	0.67	0.74	0.89	0.37	0.48	0.002
Ureasq	0.08	0.14	0.16	0.06	0.65	0.68	0.98
A x M	0.13	0.42	0.66	0.69	0.15	0.67	0.19
A x U	0.0001	0.05	0.12	0.29	0.81	0.02	0.10
M x U	0.0004	0.81	0.72	0.74	0.45	0.73	0.91
A x M x U	0.05	0.75	0.97	0.54	0.79	0.17	0.70

Table 3. The effects of method of application and urea treatment level, using a common strength (15%) of urea solution, on the chemical composition and in vitro digestion of guineagrass hay in Experiment 2B.

Method of application	Urea	CP	NDF	ADF	Cellulose	HC	ADL	IVOMD
	%							
Spray	0	5.4	75.6	44.8	37.0	30.8	7.8	41.6
	4	8.0	73.0	45.8	37.3	27.1	8.5	48.0
	6	8.2	71.6	46.1	37.3	25.6	8.8	48.0
Inject	0	5.1	74.2	44.5	36.2	29.7	8.3	40.0
	4	6.7	74.9	44.9	36.8	29.9	8.1	45.4
	6	6.9	74.5	45.7	37.1	28.8	8.6	43.0
SE		0.27	0.39	0.39	0.20	0.52	0.23	0.78
Probability values								
Application (A)		0.003	0.09	0.54	0.26	0.07	0.93	0.009
Urea (U)		0.0001	0.03	0.26	0.26	0.009	0.32	0.0003
A x U		0.10	0.01	0.94	0.57	0.04	0.55	0.002

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