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INFLUENCE OF THERMO-AMMONIATION ON FORAGE QUALITY AND UTILIZATION OF WARM-SEASON GRASS HAY

by

Roger N. Gates

A DISSERTATION

Presented to the Faculty of

The Graduate College in the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Agronomy

Under the Supervision of Dr. Steven S. Waller
and Dr. Terry J. Klopfenstein

Lincoln, Nebraska

May, 1985

TITLE

INFLUENCE OF THERMO-AMMONIATION ON FORAGE QUALITY

AND UTILIZATION OF WARM-SEASON GRASS HAY

BY

ROGER N. GATES

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INFLUENCE OF THERMO-AMMONIATION ON FORAGE QUALITY
AND UTILIZATION OF WARM-SEASON GRASS HAY

Roger N. Gates, Ph.D.

University of Nebraska, 1985

Warm-season grass hay is an important source of winter feed for cattle production in the Northern Great Plains. Frequently, these forages are harvested at mature stages. Chemical treatment offers a management tool to improve the value of this resource. This study evaluated the use of thermo-ammoniation to improve forage quality of warm-season grass hay.

Immature switchgrass, _Panicum virgatum_ L., (Swi-I), mature switchgrass (Swi-M) and mature indiangrass, _Sorghastrum nutans_ (L.) Nash, (Ind-M) were fed without treatment (CTR) or thermo-ammoniated with 3% anhydrous ammonia for 23 h at 85 C (NH3) to mature steers. Two 6 X 6 latin square trials, at _ad libitum_ or equalized intakes, were used to examine effects of thermo-ammoniation on voluntary intake, digestibility, rates of overall disappearance, rates of passage and NDF digestion, and particle size distribution of rumen digesta. Thermo-ammoniation increased digestibility, intake, rate of disappearance and rate of NDF digestion. Increases were greater with either of the mature hays than with Swi-I. Thermo-ammoniation did not affect rate of passage of undigested residues, determined from the excretion of chromium-mordanted fiber. Thermo-ammoniation improved the feeding value of mature, warm-season prairie hay; primarily by increasing digestibility and promoting increased voluntary intake.

Assumptions of a log normal distribution were invalid for weight-size frequency data resulting from wet sieving of rumen digesta. Statistical moments were calculated to describe these data. Moment analysis was appropriate, and did not suffer from the assumption of a log normal distribution neccessary for published regression techniques. Moments provided more definitive evidence of treatment effects on central tendency and dispersion of rumen digesta particle size distributions. Skewness and kurtosis could also be evaluated using moments. A greater proportion of rumen digesta had smaller particle sizes with Swi-M CTR or Ind-M CTR than with other hays.

An inexpensive, microcomputer-based, low-resolution imaging system was developed to evaluate photomicrograph slides of forage material. Machine language programming stored an image scanned by a television camera interfaced to the computer. Application programs estimated total area of a projected image or diagonal dimension of objects within the image.

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LIST OF ABBREVIATIONS

Swi-I	immature switchgrass	mo	month
Swi-M	mature switchgrass	d	day
Ind-M	mature indiangrass	h	hour
CTR	untreated	C	degrees Celcius
DM	dry matter	M	molar
NH3	thermo-ammoniated	g	gram
NDF	neutral detergent fiber	l	liter
ADF	acid detergent fiber	m	meter
IVDMD	in vitro dry matter dissappearance	um	micrometer
TDN	total digestible nutrients	cc	cubic centimeter
N	nitrogen		
NH_3	ammonia	μ	mean
Na	sodium	σ	standard deviation
Ca	calcium	log	logarithm
K	potassium	log_{10}	logarithm base 10
Cr	chromium		sum
NH_4^+	ammonium	M_1^*	first ordinary moment
NH_4^+OH	ammonium hydroxide	M_2	second central moment
NaOH	sodium hydroxide	M_3	third central moment
$KMnO_4$	potassium permanganate	M_4	fourth central moment

INFLUENCE OF THERMO-AMMONIATION ON QUALITY OF WARM-SEASON GRASS HAY FOR STEERS[1]

R. N. Gates

Summary

Warm-season grass hay is an important source of winter feed for cattle production in the Northern Great Plains. Frequently, these forages are harvested at mature stages. Chemical treatment offers a management tool to improve the value of this resource. This study was conducted to evaluate the use of thermo-ammoniation for improving forage quality of warm-season grass hay. Immature switchgrass, Panicum virgatum L., (Swi-I), mature switchgrass (Swi-M) and mature indiangrass, Sorghastrum nutans (L.) Nash, (Ind-M) were fed without treatment (CTR) or thermo-ammoniated with 3% anhydrous ammonia for 23 h at 85 C (NH3) to mature steers. Two sequential 6 X 6 latin square trials, at ad libitum or equalized intakes, were used to evaluate the influence of thermo-ammoniation on voluntary intake and digestibility, as well as rates of overall disappearance, rates of passage and NDF digestion and particle size distribution of rumen digesta. Thermo-ammoniation increased digestibility, intake, rate of disappearance and rate of NDF digestion. In general, increases were greater with either of the mature hays than with Swi-I. Rate of passage of undigested residues, as determined from the excretion of chromium-mordanted

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[1]Style and Form according to J. Anim. Sci. 59:1387.

fiber, was not affected by thermo-ammoniation. A greater proportion of the rumen digesta had smaller particle sizes with Swi-M CTR or Ind-M CTR than with the other hays which were more rapidly digested and more rapidly passed. Thermo-ammoniation markedly improved the feeding value of mature, warm-season prairie hay; primarily by increasing digestibility and allowing increased voluntary intake.

(Key Words: Beef Cattle, Warm-Season Grass Hay, Ammoniation, Intake, Digestion, Passage, Particle Size.)

Introduction

Limited attention has been given to the chemical treatment of forage derived from warm-season or C_4 plants. Most work has been confined to small grain cereal straws or other cool-season (C_3) forage plants. C_4 grasses are distinctly different from C_3 grasses in photosynthetic pathway (Waller and Lewis, 1979), tissue arrangement, and cell wall composition (Akin and Burdick, 1973, 1975; Barton and Akin, 1977) which influences their nutritive value and utilization.

Much of the winter feed supply for beef production enterprises in the Northern Great Plains comes from native hay production. Among the native species used for hay production the tall grass species, all C_4, are most important and productive. Typical production patterns emphasize stand longevity and harvest of near maximum dry matter. This results in a single annual harvest, often of mature plant material. Forage value of these plants decreased rapidly as the growing season advanced (Perry and Baltensperger, 1979; Griffin and Jung, 1983a, 1983b; Vona et al., 1984). Chemical treatment to improve the feed value of this large resource, already being harvested and fed, can improve production and efficiency for the enterprises involved. NH_3 treatment may improve the value of these materials through increased digestibility and(or) intake. It has the further advantage of increasing the N content of materials typically deficient in protein.

Hydroxides of Na, Ca and K and NH_4^+ or anhydrous NH_3 have frequently been used as an economical means to improve the feed value of crop residues and related by-products (Klopfenstein, 1978). Fewer investigations have considered the chemical treatment of hay. Ammonia was evaluated for use as a preservative of hay baled at high moisture levels (Knapp et al., 1974). More recently, hay has been treated with NH_3 with the intention of improving feeding value (Wylie, 1981; Buettner et al., 1982; Moore et al., 1983; Ocumpaugh et al., 1984; Grotheer et al., 1984; Moore et al., 1985).

This study was conducted to determine the extent of improvement in the forage quality of warm-season grass hay treated with NH_3, to evaluate the role of digesta passage in hay utilization and to examine the effect of plant maturity on the response to NH_3 treatment. Variables of interest included voluntary intake and apparent digestibility. Rumen fill, fecal output, rates of disappearance and rate of particulate passage were also measured to evaluate the interrelationships between plant material, treatment, and passage. Rumen evacuation and a marker (Cr-mordanted fiber) were both used to evaluate digesta disappearance. Particle size distribution of rumen digesta was estimated for comparison with other digestion and passage parameters.

Experimental Procedure

Six mature beef steers (407 kg), with permanent rumen fistulae fitted with cannulae, were assigned in two sequential phases of an intake and digestion trial. Each phase involved a 6 X 6 latin square design of periods and animals with a 3 X 2 factorial arrangement of treatments. Treatments included three hay types, immature and mature switchgrass (Panicum virgatum L.) and mature indiangrass [Sorghastrum nutans (L.) Nash], either untreated or thermo-ammoniated. Immature switchgrass was harvested June 22 when .9 m high, with the apical meristem elevated to .4 m; characterized as "mid-joint" stage. Mature hays were harvested September 15 with switchgrass at a "ripe-seed" stage and indiangrass at "soft-dough" stage, typical of its later maturing habit. Thermo-ammoniation involved exposure for 23 h at 85 C to anhydrous NH_3 (3% of dry matter) in the sealed chamber of a commercial NH_3 straw processing plant[1]. All hays were stored indoors and ground through an 8 cm screen in a tub grinder before feeding.

In the first phase of the trial, the latin square was completed at ad libitum intake (feed offered at levels to achieve 10% refusal). Immediately following, a re-randomization was employed and intake was equalized by offering feed at a level equivalent to the minimum intake encountered during the first

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[1]Flemstofte-Mads Amby Maskinfabriker A/S

phase (1.2 kg DM/ 100 kg body weight). Daily feed was offered at 0600, 0900, 1200 and 1500 h in four equal portions comprising 55% of the daily offer. The remainder was offered at 1800 h. Salt (20 g) and dicalcium phosphate (70 g) were top-dressed daily at the 600 feeding. An aqueous solution of urea (35.8 g/l) was sprinkled on the mature, untreated hays at each feeding to provide 17.9 g urea/kg DM according to the urea fementation potential calculation (Burroughs et al., 1975). A TDN concentration of 48% [mature prairie hay, (NRC, 1976)] without any available NH_3 nitrogen was assumed for these materials. All required N was supplied from added urea, ignoring the small protein content of these forages. This was done to ensure a supply of rumen NH_3 adequate for maximum fiber utilization.

Animals were housed indoors in slatted-floor stalls with water available continuously. During fecal collection periods, collection bags were attached using harnesses. Bags were changed twice daily immediately before feeding at 600 and 1800 h.

During the ad libitum phase, each period consisted of 5 d of pre-feeding, 7 d of recorded feeding and fecal collection with an assumed lag of 48 h between feeding and fecal collection, an interim day and a final day for rumen evacuation. At equal intake each period was 12 d; 5 d pre-feed, 6 d collection and 1 d evacuation. Animals were weighed on the last day of pre-feeding during each period. Mean weights during the ad libitum phase were

used for the estimate of body weight in all feed intake calculations.

Grab samples of feed (100 g/d during ad libitum phase; 50 g/d during equal intake phase) and orts (5%/d) were retained for dry matter and chemical analysis. Fecal samples (10% of total collection) were retained and refrigerated, and a composite subsample taken for each period.

Samples of feed, orts, rumen contents and feces were dried to constant weight at 60 C for dry matter determination. A further subsample was ground through a 1 mm screen and analyzed for NDF, ADF, and permanganate lignin. Following NDF determination, the residue was used for sequential ADF determination (Goering and Van Soest, 1970). Separate samples were ashed at 500 C to determine organic matter. Crude protein of hay samples was determined using a macro Kjeldahl procedure (AOAC, 1975). Digestibility was estimated in vitro on initial hay samples using a two stage procedure (Tilley and Terry, 1963). Urea was included in the buffer for the mature, untreated hays.

Retention Time and Disappearance Rates

Two techniques were used to evaluate the disappearance of forage from the digestive tract. A marker, Cr-mordanted fiber (Uden et al., 1980.), was used to estimate passage of undigested fiber out of the rumen. The ratio of rumen contents (estimated by digesta removal) to daily intake was used to estimate retention time.

Cr-mordanted Fiber. A portion of each hay was used to prepare Cr-mordanted material to serve as a digesta marker. Hay was ground with a hammer mill (8 mm screen), washed with chlorine free laboratory detergent, rinsed, treated with sodium dichromate and rinsed until free of color. Acetic acid was used to acidify the final rinse (Uden et al., 1980).

A single dose (800 g) of Cr-mordanted fiber was introduced through the rumen cannula at 0600 h, 4 d before the final fecal collection. Fecal samples were obtained at 12 h intervals from 12 to 96 h post dosing. Fecal production at each 12 h interval was subsampled using a 50 cc plastic syringe from which the closed end was removed. The remaining cylinder was pushed into the feces at random locations. Samples were removed by depressing the syringe plunger. These samples were frozen for later determination of Cr concentration by atomic absorption spectroscopy (Williams et al., 1962).

Each sample consisted of a 12 h collection. Time midpoints between each collection were assumed to represent time after dosing (Uden et al., 1980). Non-linear regression was used to fit fecal Cr concentration data for each animal-period combination to a time-dependent, one compartent model (Pond et al., 1982):