UTILIZATION OF AMMONIATED ROUGHAGES

BY RUMINANTS

by

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CHAPTER I

INTRODUCTION

Utilization of agricultural by-products has been a matter of concern for centuries. The steady increase in human population with the resultant drain on natural resources make it imperative that continued effort be exerted in the search for potential uses for agricultural by-products throughout the world.

Agricultural by-product roughages include rice hulls, sorghum stubble, and wheat straw. The growth of the cattle feeding industry has aroused interest in these by-product roughages, which are plentiful, but utilized relatively little. The use of all concentrate and/or high concentrate rations has been developed to partly relieve the difficulties involved in mechanization and transportation of roughage; however, feedlot data continue to support the need of some roughage by finishing steers.

Recently, the discovery that treating by-product roughages with a gaseous nitrogen compound under specific conditions of pressure and temperature (ammoniation) improved the crude protein equivalent of these roughages. In general, the additional nitrogen fixation on the roughage product may be increased by increasing the temperature, pressure, or contact time with the nitrogen-containing gas or any combination of these variables (United States Patent Office, 1966). In using the end product as cattle feed, a relatively low pressure and temperature of 250 p.s.i. and 350° F for a period of thirty minutes produces a roughage containing not less than 1.6% nitrogen which is equivalent to a protein content of 10%.

Research information is limited concerning the use of ammoniated roughages as a component of high energy finishing rations for ruminants. The finishing trial in this study was designed to compare the feeding value of ammoniated rice hulls to sorghum stubble and wheat straw when fed both as ammoniated and non-ammoniated materials and to study the effect of ammoniation on sorghum stubble and wheat straw. Digestibility studies were conducted with both sheep and cattle to evaluate the nutritive value of ammoniated rice hulls when compared to sorghum stubble and wheat straw, both ammoniated and non-ammoniated, and to study the effects of ammoniation on the nutritive value of sorghum stubble and wheat straw. The digestibility study with steers was also designed for a comparison of actual fecal dry matter output obtained by the total collection method and predicted fecal dry matter output obtained by the chromic oxide indicator method.

CHAPTER II

REVIEW OF LITERATURE

Most research conducted concerning ammoniated roughage products as an ingredient of ruminant finishing rations has concerned utilization of ammoniated rice hulls. Rice hulls are a by-product of the rice milling industry and thus are available for livestock feed. The growth of the cattle feeding industry in the Texas Panhandle has recently aroused interest in two other by-product roughages, grain sorghum stubble and wheat straw. Ammoniation of these roughages could result in a product that has merit as an ingredient of high energy finishing rations for ruminants.

With careful management, all-concentrate rations have been used successfully for finishing slaughter cattle. However, at least some roughage or roughage substitute is used in fattening rations by the majority of cattle feeders to minimize repercussions resulting from errors in management. All-concentrate rations have usually been compared to rations containing approximately 20% roughage. Wise et al. (1961), Davis, Oltjen, and Bond (1963), and White, Reynolds, and Klett (1969) found similar gains and concentrate intake on all-concentrate and 20% roughage rations. White and Reynolds (1969) reported higher gain and feed intake with a 20% roughage ration than with all-concentrate.

Finishing trials. Roughage source has a marked influence on cattle performance. Klett et al. (1972) stated that roughage fed at low levels is not expected to contribute to the energy content of the ration, but rather to serve in slowing the rate of passage of the feed through the digestive tract. This in turn allows a more uniform and complete digestion of the grain portion of the ration.

White (1966) reported that sudangrass hay was significantly superior to ammoniated rice hulls when fed at the 40% roughage level, but not at the 20% roughage level. Digestive disturbances were also frequent in cattle receiving a 40% raw rice hull level, but were not present in cattle receiving the 40% ammoniated rice hull level.

A study by Furr and Carpenter (1967) compared an all-concentrate grain sorghum ration with a 10% ammoniated rice hull ration. They found no significant differences in average daily gain or between various carcass characteristics between treatments.

Several researchers (Eng, 1964; Conrad, Neal, and Riggs, 1965; Harvey et al., 1968; and Tillman et al., 1969) indicated that low levels of ammoniated rice hulls may be used to replace ground sorghum grain in high-grain bovine finishing rations without a significant reduction in the feeding value of the total ration. They also indicated that very little digestible energy was derived from the added roughage and that roughage, when substituted for grain, served to improve the utilization of the remaining grain by reducing the rate of passage through the digestive tract.

Lippke and Riewe (1971) reported data on ammoniated grain sorghum stubble and ammoniated wheat straw. In that study, rice hulls, grain sorghum stubble, and wheat straw, all ammoniated, were fed in a 10% ration to finishing steers. They found no significant differences in gain, feed intake, or feed conversion.

Digestibility studies. White (1966) conducted two digestibility studies utilizing sudangrass hay, rice hulls, and ammoniated rice hulls in 40% and 20% rations. In both rations, dry matter, crude fiber, and total digestible nutrients were higher ($P < .01$) for the sudangrass hay ration than for either the rice hull or ammoniated rice hull rations. He found that crude protein digestibility was lowest ($P < .01$) in the ammoniated rice hull ration when fed at the 40% level. However, crude protein was equally digested in the rations containing ammoniated rice hulls or sudangrass hay at the 20% level.

Eng (1964) reported a digestibility study in which ammoniated rice hulls were compared to cottonseed hulls in a 30% roughage ration. He found the digestibility of dry matter, crude fiber, organic matter, and energy was significantly higher for the cottonseed hulls, but protein digestibility was higher ($P < .01$) for the ammoniated rice hulls. He stated that since the crude fiber was approximately 50% silica, the silica forms a protective coating and serves as a mechanical obstruction to digestion of the fiber portion of ammoniated rice hulls. He also reported that the nitrogen in ammoniated rice hulls was released slower than urea nitrogen. However, several other researchers (Davis et al., 1955; King et al., 1957; and Hershberger et al., 1959) have reported that ammoniated product nitrogen is not as available as that from natural protein or urea.

Tillman et al. (1969) found that levels of up to 9% ammoniated rice hulls did not affect the digestibility of nitrogen or organic matter in finishing rations. They indicated that ammoniated rice hulls can be used to replace sorghum grain in an all-concentrate diet, up to 9% of the ration, without decreasing the feeding value of the ration.

Chromic oxide. The first suggestion for using an indicator in determining digestibility values was made by Wildt (1874) who proposed the use of silica. Since that time, numerous other indicators have been used to determine digestibility, with chromic oxide being used more often than others.

Indicators may be divided into two categories: (a) internal and (b) external. Internal indicators, occurring naturally in the plant compounds are used to estimate apparent digestibility. The most widely used internal indicator is nitrogen. External indicators are inert, indigestible substances that are added to the diet or given directly to the animal in known amounts and used to determine fecal output. The principle for using external indicators to estimate fecal output after a stabilizing period is based on an equilibrium between daily output and daily input of the indicator. The most widely used external indicator is chromic oxide.

Fecal output (calculated using external indicators) and digestibility (calculated using internal indicators) can be calculated by the use of the following equations (Lopez, 1969).

$$\text{Fecal output} = \frac{\text{wt. of ext. ind. fed}}{\text{wt. of ext. ind./g dried feces}}$$

$$\text{Digestibility} = \frac{\text{conc. int. ind. in feces-conc. in feed}}{\text{conc. of int. ind. in feces}} \times 100$$

The feasibility of chromic oxide as a means of measuring the fecal output of an animal is dependent upon the quantitative recovery of the material in the feces. An indicator material should be recovered in the feces at a consistent rate if complete recovery is not possible to be successfully used as a means of measuring fecal output. Proper corrections then can be made for the estimation of fecal output. The adequacy of consistent recovery might be directly related to three factors: diurnal excretion of chromic oxide, processing of feces for chemical analysis, and accuracy of chemical analysis (Alpan, 1965).

Diurnal variation in the excretion of chromic oxide has been reported by many workers. Hardison and Reid (1953) employed a detailed fecal grab sampling plan and found that the chromic oxide content of feces voided at various intervals during the day was extremely variable. However, the nature of chromic oxide excretion pattern indicated that the amount of fecal output could be estimated from samples of feces taken at any time, provided the rate of recovery of chromic oxide is known.

Lancaster _et al_. (1953) also reported daily variation in the excretion of chromic oxide. They reported lower concentrations of chromic oxide in the afternoon samples. Their conclusion was that the fecal output could be predicted accurately from morning grab samples.

Davis _et al_. (1958) found considerable variations in the chromic oxide content of the feces samples taken at various hours of the day, regardless of whether chromic oxide was administered once or twice daily. However, twice daily administration of chromic oxide seemed to lessen the variation in excretion.

Alpan (1965) reported uniform rates of excretion with a recovery rate of 99.8% when animals were dosed and sampled at 7:00 a.m. and 4:00 p.m. Pryor (1966) reported an almost equally desirable recovery rate and a regular diurnal variation when dosing at 8:00 a.m. only.

A study by Lopez (1969) showed that chromic oxide used as an external indicator gave a recovery rate of chromic oxide in the feces sufficiently high enough to predict fecal output. He also found no statistical differences between total collection and "grab-sampling" techniques for estimating fecal output.

Total collection. In general, the conventional method for determining digestibility of feedstuffs is the total collection technique. This involves recording the amount of nutrients consumed and total collection of the feces (Maynard and Loosli, 1962). Apparent digestibility is the term for the fraction of nutrient consumed that is not excreted in the feces. The percentage of each nutrient digested is called the digestion coefficient for that nutrient.

In conventional digestion studies, animals are confined in special metabolism stalls to facilitate collection of feces and/or urine. Another method is the collection of feces with the aid of bags attached to the animals.

As previously stated, the total collection method for calculating digestibility requires an accurate record of feed intake and of feces output. From this information, together with a chemical analysis of the nutrient in the feed and feces, the digestibility of a nutrient is calculated. This was shown in an equation by Crampton and Harris (1969).

$$\%\ \text{Dig.} = \frac{\begin{matrix}\text{dry wt. of} \\ \text{diet eaten}\end{matrix} \times \begin{matrix}\text{\% of nut.} \\ \text{in diet}\end{matrix} - \begin{matrix}\text{dry wt. of} \\ \text{feces voided}\end{matrix} \times \begin{matrix}\text{\% of nut.} \\ \text{in feces}\end{matrix}}{\text{dry wt. of diet eaten} \times \text{\% of nut. in diet}} \times 100$$

CHAPTER III

EXPERIMENTAL PROCEDURE

The roughages used in these studies except for the raw sorghum stubble and raw wheat straw in the steer digestibility trial were produced in Southeastern Texas and those which were ammoniated were treated at Delta Industries, Houston, Texas. The raw sorghum stubble and the raw wheat straw used in the steer digestibility trial were produced in the High Plains of Texas. The sorghum grain was obtained at a commercial elevator from supplies grown within the local vicinity and fed dry rolled in all trials.

Finishing trial. Seventy-five uniform crossbred steers averaging 348 kg were randomly allotted into five main treatment groups with three replications of five steers in each main treatment for a 101 day feeding period. Composition of the finishing rations (11.5% crude protein, as fed) is given in table 1. All steers were implanted with 30 mg diethylstilbesterol at the initiation of the study. The steers received the rations (table 1) on the 1st day and were self-fed throughout the feeding period. Steers were weighed at three 28 day intervals and a final 17 day interval with initial and final live weights determined from unshrunk weights using a 3% and 4% arithmetical shrink, respectively. All steers were slaughtered upon completion of the feeding period. Performance criteria were individual daily gain, daily feed intake, and feed per kg of gain. Carcass measurements included grade, back fat thickness, marbling score, dressing percent, conformation score, and abscessed livers. Statistical analyses were by analysis of variance.

TABLE 1. COMPOSITION OF FINISHING RATIONS

Ration[a]	ARH	SS-A	RSS	WS-A	RWS
Ingredient composition	%	%	%	%	%
Sorghum grain[b]	84.0	84.0	83.2	84.0	83.8
Cottonseed meal	5.0	5.0	5.0	5.0	5.0
Calcium carbonate	.5	.5	.5	.5	.5
Trace mineral salt	.5	.5	.5	.5	.5
Roughage source	10.0	10.0	10.0	10.0	10.0
Aureomycin	.035	.035	.035	.035	.035
Vitamin A	.015	.015	.015	.015	.015
Urea	--	--	.25	--	.25

[a]Abbreviations for rations are the following: ammoniated rice hulls, ARH; ammoniated sorghum stubble, SS-A; raw sorghum stubble, RSS; ammoniated wheat straw, WS-A; raw wheat straw, RWS. These abbreviations will be used in all tables of this report.

[b]Sorghum grain was dry rolled.

Sheep digestibility study. Twenty-four crossbred wethers averaging 44 kg were placed in metabolism stalls and randomly allotted five per treatment except the ammoniated rice hull treatment which received four, respectively. Ingredient composition of the total ration and chemical composition of the ammoniated and non-ammoniated roughages are listed in table 2 and chemical composition of the total ration is given in table 3. A 7-day adjustment period, followed by a 7-day preliminary period was used to establish intake at approximately 1160 g of dry matter daily in two feedings. All animals were fed 20 mg chlortetracycline daily. Water was provided *ad libitum* throughout the trial. Rations were sampled at each feeding. Total wet feces were weighed and sampled (10% aliquot) throughout the 7-day collection period. Total daily urine was diluted to a constant volume with a 100 ml aliquot composited for analysis. Fecal samples were frozen and the urine samples were refrigerated until analyzed. Proximate analysis of feed and feces and urinary nitrogen analysis were conducted according to A.O.A.C. (1965) methods. Gross energy determinations were made using a Parr oxygen bomb, adiabatic calorimeter. True protein digestibility was calculated using the value of 0.45 g metabolic fecal nitrogen per 100 g dry matter intake (Blaxter, 1964). Total digestible nutrients were calculated using the value of 4.41 kcal digestible energy per g TDN (N.R.C., 1969). Statistical analyses were by analysis of variance and mean separation was accomplished by the use of Duncan's multiple range test.

Steer digestibility study. Twenty steers averaging 206 kg were placed in metabolism stalls and randomly assigned four per treatment to each of the five roughage treatments. Only ten metabolism stalls were

TABLE 2. INGREDIENT COMPOSITION OF TOTAL RATION AND CHEMICAL COMPOSITION OF AMMONIATED AND NON-AMMONIATED ROUGHAGES USED IN SHEEP DIGESTIBILITY STUDY

Ration	ARH	SS-A	RSS	WS-A	RWS
Ingredient composition	%	%	%	%	%
Roughage	40.00	40.00	40.00	40.00	40.00
Molasses	5.00	5.00	5.00	5.00	5.00
Sorghum grain[a]	53.10	53.40	52.10	52.80	52.10
Urea	0.30	--	1.31	0.65	1.32
Calcium carbonate	0.50	0.50	0.50	0.50	0.50
Trace mineral salt	1.00	1.00	1.00	1.00	1.00
Elemental sulfur	0.10	0.10	0.10	0.10	0.10
Roughage composition[b]					
Organic matter	77.89	84.12	88.16	89.71	92.64
Ash	22.11	15.88	11.84	10.29	7.36
Crude protein	10.12	12.07	3.15	7.60	3.10
Ether extract	1.04	1.20	1.49	0.75	1.25
Crude fiber	42.49	38.10	31.91	41.49	41.71
Nitrogen-free extract	23.79	32.79	51.61	39.87	46.58
Gross energy, kcal/g DM	3.698	3.892	4.000	4.204	4.184

[a]Sorghum grain was dry rolled.

[b]DM basis.

TABLE 3. CHEMICAL COMPOSITION OF RATIONS USED IN SHEEP DIGESTIBILITY STUDY

Ration	ARH	SS-A	RSS	WS-A	RWS
Chemical composition[a]	%	%	%	%	%
Organic matter (OM)	87.07	91.01	92.56	91.80	93.60
Non-protein OM	76.69	80.57	82.18	81.36	83.16
Ash	12.93	8.99	7.44	8.20	6.40
Crude protein	10.38	10.44	10.38	10.44	10.44
Ether extract	2.29	2.40	2.24	2.40	1.95
Crude fiber	21.34	18.44	14.20	21.43	20.94
N-free extract	53.06	59.53	65.74	57.53	60.27
Gross energy, kcal/g DM	4.077	4.220	4.206	4.231	4.263

[a]DM basis.

available, so two trials were conducted with two animals per treatment in each trial. Ingredient composition of the total ration and chemical composition of the ammoniated and non-ammoniated roughages are listed in table 4 and chemical composition of the total ration is given in table 5. A 7-day adjustment period, followed by a 7-day preliminary period was used to establish intake at approximately 4.27 kg of dry matter daily in two feedings. Also, 7.5 g of air dry chromic oxide was added to each individual feeding, thoroughly mixed, and fed along with the ration. Water was provided ad libitum throughout the trial. Rations were sampled at each feeding. Total wet feces were weighed and sampled (10% aliquot) at approximately 8:00 a.m. each morning of the 7-day collection period. Urine was not collected. Fecal samples were frozen until analyzed. Proximate analysis of feed and feces were conducted according to A.O.A.C. (1965) methods. Gross energy determinations were made using a Parr oxygen bomb, adiabatic calorimeter. A modified method of Christian and Coup (1963) was utilized in analyzing all fecal samples for chromic oxide content. True protein digestibility was calculated using the value of 0.45 g metabolic fecal nitrogen per 100 g dry matter intake (Blaxter, 1964). Total digestible nutrients were calculated using the value of 4.41 kcal digestible energy per g TDN (N.R.C., 1969). Statistical analyses were by analysis of variance and mean separation was accomplished by the use of Duncan's multiple range test.

TABLE 4. INGREDIENT COMPOSITION OF TOTAL RATION AND CHEMICAL COMPOSITION OF AMMONIATED AND NON-AMMONIATED ROUGHAGES USED IN STEER DIGESTIBILITY STUDY

Ration	ARH	SS-A	RSS	WS-A	RWS
Ingredient composition	%	%	%	%	%
Roughage	40.00	40.00	40.00	40.00	40.00
Molasses	5.00	5.00	5.00	5.00	5.00
Sorghum grain[a]	53.38	53.46	53.18	53.44	52.76
Urea	0.44	0.36	0.64	0.37	1.06
Calcium carbonate	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50
Elemental sulfur	0.10	0.10	0.10	0.10	0.10
Aureomycin	0.07	0.07	0.07	0.07	0.07
Vitamin A	0.015	0.015	0.015	0.015	0.015
Roughage composition[b]					
Organic matter	76.18	81.18	94.82	83.28	91.43
Ash	23.82	18.82	5.18	16.72	8.57
Crude protein	9.31	9.96	8.16	9.84	5.03
Ether extract	1.24	1.40	1.92	1.32	1.48
Crude fiber	45.95	39.74	30.33	47.95	40.24
Nitrogen-free extract	19.68	30.08	54.41	24.17	44.68

[a]Sorghum grain was dry rolled.

[b]DM basis.

TABLE 5. CHEMICAL COMPOSITION OF RATIONS USED IN STEER DIGESTIBILITY STUDY

Ration	ARH	SS-A	RSS	WS-A	RWS
Chemical composition[a]	%	%	%	%	%
Organic matter (OM)	88.97	89.94	95.28	90.52	94.10
Non-protein OM	78.66	79.41	84.69	79.99	83.54
Ash	11.03	10.06	4.72	9.48	5.90
Crude protein	10.51	10.53	10.59	10.53	10.56
Ether extract	2.48	2.96	2.55	2.59	3.74
Crude fiber	20.81	19.12	18.60	23.13	19.78
N-free extract	55.37	57.33	63.54	54.27	60.02
Gross energy, kcal/g DM	4.092	4.098	4.288	4.203	4.255

[a]DM basis.

CHAPTER IV

RESULTS AND DISCUSSION

Finishing trial. Feedlot performance and carcass data are given in table 6. There were no significant differences between treatments for any of the measured variables. There was a trend for improved daily gains and feed conversion in the raw wheat straw treatment as compared to the ammoniated wheat straw and both sorghum stubble treatments. Carcass traits were not affected significantly by roughage source.

The ammoniated rice hull ration had the most efficient feed conversion ratio, but had the lowest average daily gain of all experimental rations. This was probably a function of the lower feed consumption. These data suggest a slower rate of passage from the reticulo-rumen which resulted in a more efficient utilization when compared to the other rations. Lippke and Riewe (1971) reported similar results in a study utilizing comparable ammoniated roughage rations.

Ammoniation of the roughage materials in this trial did not improve performance over the same materials when fed in the non-ammoniated form with added urea to increase the nitrogen level to that of the ammoniated product. Tillman *et al*. (1969) found no significant differences in the feedlot performance of steers when comparing all-concentrate, ammoniated rice hull (3,6, and 9% levels), and raw rice hull (3,6, and 9% levels) rations. Furr and Carpenter (1967) also reported no significant differences between an all-concentrate ration and a 10% ammoniated rice hull ration.

TABLE 6. FEEDLOT PERFORMANCE AND CARCASS TRAITS OF STEERS FED ROUGHAGE RATIONS (AMMONIATED AND NON-AMMONIATED)

Ration	ARH	SS-A	RSS	WS-A	RWS
No. Steers	15	15	15	15	15
Initial wt., kg	345.70	348.30	352.50	347.40	351.00
Final wt., kg	463.50	468.50	474.00	471.20	484.50
Total gain, kg	117.80	120.20	121.50	123.80	133.50
Daily gain, kg	1.16	1.19	1.20	1.22	1.32
Daily feed cons., kg	10.84	12.65	13.25	12.90	12.64
Feed/gain, kg	9.34	10.63	11.04	10.57	9.58
Hot carcass wt., kg	295.60	294.20	302.00	296.10	300.90
Dressing %	63.00	62.00	63.00	62.00	62.00
Backfat thickness, cm	1.22	1.14	1.17	1.17	1.24
Marbling score[a]	4.70	4.70	5.10	4.70	5.00
Conformation score[b]	12.10	12.70	13.20	13.20	13.40
Carcass grade[b]	11.50	11.10	11.70	11.40	11.30
Absessed livers, %	6.67	0.00	0.00	0.00	6.67

[a]Slight = 4; small = 5; moderate = 7.

[b]Good plus = 11; choice minus = 12; average choice = 13; etc.

Data from this trial suggest that the materials (ammoniated and non-ammoniated) utilized can be used as roughage sources in feedlot finishing rations. However, the level of incorporation into the ration will probably be limited because these roughages are not added to supply energy, but to slow the rate of passage of the digesta through the tract and allow more time for digestibility and utilization of other ration components. Average daily gains, feed consumption, and feed conversion would be expected to improve with these materials as levels are reduced in the rations.

Sheep digestibility study. Sheep digestibility data are presented in table 7. Digestibility of both dry matter and organic matter was significantly higher ($P < .05$) for the raw sorghum stubble ration when compared to all other rations. Non-protein organic matter digestibility was also higher for the raw sorghum stubble ration when compared to the ammoniated sorghum stubble ration and significantly higher ($P < .05$) when compared to all others. Also, the digestibility coefficients for dry matter, organic matter, and non-protein organic matter of the raw wheat straw ration were higher, although the differences are not significant, when compared to the ammoniated wheat straw ration.

Crude fiber digestibility was significantly lower ($P < .01$) for the ammoniated rice hull ration when compared to all others and significantly lower ($P < .01$) for the ammoniated wheat straw ration when compared to both sorghum stubble rations and the raw wheat straw ration. This was possibly because the crude fiber of both the ammoniated rice hull and ammoniated wheat straw ration contained a higher percentage of silica than

TABLE 7. DIGESTIBILITY OF ROUGHAGE RATIONS (AMMONIATED AND NON-AMMONIATED) BY SHEEP

Ration	ARH	SS-A	RSS	WS-A	RWS
Daily DM intake, kg	1.203	1.190	1.167	1.179	1.081
Digestibility, %					
Dry matter	56.10^{d}	65.30^{b}	69.50^{a}	60.70^{c}	$63.80^{b,c}$
Organic matter (OM)	61.75^{c}	68.27^{b}	72.26^{a}	63.01^{c}	$65.48^{b,c}$
Non-protein OM	62.07^{b}	70.45^{a}	72.99^{a}	63.42^{b}	65.55^{b}
Ether extract	$74.70^{b,c}$	79.51^{b}	73.65^{c}	85.16^{a}	72.18^{c}
Crude fiber	14.52^{g}	44.41^{e}	45.56^{e}	30.54^{f}	44.96^{e}
N-free extract	80.63^{a}	78.12^{a}	78.90^{a}	$74.77^{b,c}$	72.86^{c}
Gross energy	59.73^{c}	65.80^{b}	69.91^{a}	60.37^{c}	$62.51^{b,c}$
Crude protein	59.36^{b}	51.59^{c}	66.50^{a}	59.83^{b}	64.90^{a}
True protein	86.46^{b}	78.59^{c}	93.59^{a}	86.80^{b}	91.86^{a}
Daily N retention, g	3.40	3.38	3.95	2.70	2.63
Digestible energy, kcal per g DM	2.435	2.777	2.940	2.554	2.665
TDN, DM basis, %	55.89	64.53	68.95	60.41	63.28

^{a,b,c,d}Means within the same category having different superscripts are significantly different ($P < .05$).

^{e,f,g}Means within the same category having different superscripts are significantly different ($P < .01$).

the crude fiber of the other rations. Eng (1964) found similar results in a study with ammoniated rice hulls. Gross energy digestibility for the raw roughages was significantly higher ($P < .05$) when compared with the ammoniated roughages.

Digestibility of the protein fraction of the raw roughages was higher ($P < .05$) than that of the ammoniated roughages indicating that the nitrogen supplied by urea was more readily available than the nitrogen supplied by ammoniation. These data are supported by those of Davis *et al*. (1955), King *et al*. (1957), and Hershberger *et al*. (1959). There were no significant differences in nitrogen retention.

Steer digestibility study. Digestibility data are shown in table 8. Dry matter, organic matter, and non-protein organic matter digestibilities were significantly higher ($P < .05$) for the raw wheat straw ration when compared to the ammoniated wheat straw ration and higher, although not significantly, for the raw sorghum stubble ration when compared with the ammoniated sorghum stubble ration.

Crude fiber digestibility was significantly higher ($P < .05$) for the raw roughage rations. This closely agrees with the sheep digestibility study, except that digestibility of the crude fiber protein of the ammoniated sorghum stubble decreased and was significantly lower ($P < .01$) than that of the raw roughage rations. Nitrogen free extract digestibility was higher ($P < .05$) for the ammoniated roughages. There were no significant differences in gross energy digestibility; however, values for the raw roughage rations were slightly higher than the values for the ammoniated roughage rations.

TABLE 8. DIGESTIBILITY OF ROUGHAGE RATIONS (AMMONIATED AND NON-AMMONIATED) BY STEERS

Ration	ARH	SS-A	RSS	WS-A	RWS
Daily DM intake, kg	4.200	4.160	4.320	4.390	4.280
Digestibility, %					
Dry matter	56.77^{b}	$61.30^{a,b}$	66.09^{a}	56.38^{b}	66.58^{a}
Organic matter (OM)	$62.89^{a,b}$	$66.79^{a,b}$	68.46^{a}	60.92^{b}	68.71^{a}
Non-protein OM	64.49^{c}	$69.89^{a,b}$	70.31^{a}	$64.81^{b,c}$	70.27^{a}
Ether extract	68.75^{b}	80.06^{a}	77.50^{a}	$75.00^{a,b}$	79.71^{a}
Crude fiber	17.82^{f}	39.28^{e}	57.92^{d}	25.02^{f}	58.25^{d}
N-free extract	81.66^{a}	79.73^{a}	73.47^{b}	79.46^{a}	73.66^{b}
Gross energy	61.08	63.66	65.66	58.19	65.85
Crude protein	52.08	43.83	53.53	39.56	56.32
True protein	78.46	70.54	80.09	66.57	83.25
Digestible energy, kcal per g DM	2.499	2.609	2.816	2.446	2.802
TDN, DM basis, %	58.14	63.18	67.59	57.46	68.39

[a,b,c]Means within the same category having different superscripts are significantly different ($P<.05$).

[d,e,f]Means within the same category having different superscripts are significantly different ($P<.01$).

Both crude protein and true protein digestibilities were higher, although not significantly, for the raw roughage rations. Since the raw roughages utilized in this experiment were higher in protein, less urea was needed to make the rations isonitrogenous than was necessary in the sheep rations. This indicates that natural nitrogen or nitrogen supplied by urea was more available than nitrogen supplied by ammoniation.

The results of the sheep and steer digestibility trials indicate that the nutritive value of the raw sorghum stubble ration and the raw wheat straw ration were superior to their homologous ammoniated rations and to the ammoniated rice hull ration. However, this seems to apply only when the roughage portion of the ration is 40% or higher. Studies by Lippke and Riewe (1971), Tillman et al. (1969), Furr and Carpenter (1967), and the finishing study reported herein indicate that ammoniated rice hulls, sorghum stubble (both raw and ammoniated), and wheat straw (both raw and ammoniated), can be incorporated in finishing rations at a low level without any significant effect on animal performance. The feasibility of ammoniating these materials depends on economics involved in harvesting and transportation.

Chromic oxide. Data from the chromic oxide study are shown in table 9. Recovery rate of chromic oxide was lower than the recovery rates reported by various researchers (Lopez, 1969; Elam et al., 1962; Pryor, 1966; and Alpan, 1965). Chromic oxide, when fed in dry form in a ration, seems to adhere easily to any object. In the study reported herein, small amounts of chromic oxide adhered to the feed bunks and muzzles of the animals, however, they were small and considered as insignificant. The mean average difference between the predicted and actual fecal dry

TABLE 9. CHROMIC OXIDE RECOVERY IN FECES AND FECAL DRY MATTER OUTPUT (FDMO) OF STEERS

Ration	Recovery of CR_2O_3[a] %	Actual FDMO[a] g	Predicted FDMO[a] g	Difference[a] g
ARH	93.42	1810	1935	125
SS-A	91.71	1612	1755	143
RSS	90.89	1475	1675	200
WS-A	87.03	1917	2201	284
RWS	90.06	1428	1588	160
Average	90.62	1649	1831	182[b]

[a]All values were an average of four animals.

[b]Overall mean difference was significantly different ($P < .01$) from 0.

matter output was significantly different ($P < .01$) from zero. The data reported herein indicate that the chromic oxide indicator method was not as accurate as the total collection method for estimating fecal dry matter output. The lowered recovery rate of chromic oxide could have possibly been due to method of feeding chromic oxide, to diurnal variation in excretion, to sampling procedures, or to chemical analysis. Other researchers (Elam *et al.*, 1962; Crampton and Lloyd, 1951; Davis *et al.*, 1958; Pryor, 1966; and Alpan, 1965) reported high recovery rates when using various methods of administering chromic oxide.

CHAPTER V

SUMMARY

A finishing trial with steers and digestibility studies with both wethers and steers were conducted to evaluate and compare sorghum stubble (both ammoniated and non-ammoniated), wheat straw (both ammoniated and non-ammoniated), and ammoniated rice hulls as a roughage source in high energy finishing rations. The steer digestibility study was also utilized for a comparison of the total collection method and the chromic oxide indicator method for estimating fecal dry matter output. Roughage and crude protein levels of the isonitrogenous rations utilized for the finishing trial, the sheep digestibility trial, and the steer digestibility trial were as follows: 10, 11.5; 40, 10.4; and 40, 10.5.

There were no significant differences between treatments for average daily gain, feed consumption, feed conversion, or carcass characteristics in the finishing trial. In the sheep digestibility study, digestion coefficients for dry matter, organic matter, and gross energy were higher ($P < .05$) for the raw sorghum stubble treatment. Crude fiber digestibility was significantly lower ($P < .01$) for the ammoniated rice hull treatment. Crude and true protein digestibilities were significantly higher ($P < .05$) for the raw roughage treatments. Digestibility of dry matter, organic matter, and non-protein organic matter in the steer digestibility study was significantly higher ($P < .05$) for the raw wheat straw treatment when compared to the ammoniated wheat straw treatment. Crude fiber digestibility was significantly higher ($P < .01$) for the raw roughage treatments.

Both crude and true protein digestibilities were higher for the raw roughage treatments, although the differences were not significant. There was a trend for increased digestibility of all major feed components except ether extract and nitrogen-free extract for the raw roughage treatments. Ammoniation of the roughages in these studies did not improve the performance nor digestibility over the same materials fed in the non-ammoniated form with added urea to increase the nitrogen level to that of the ammoniated product. Data from these trials suggest that ammoniated and non-ammoniated roughages can be used as roughage sources in feedlot finishing rations, when incorporated in low levels, without significantly affecting performance.

Mean chromic oxide recovery rates (%) in the steer digestibility trial were 93.42, 91.71, 90.89, 87.03, and 90.06 for ammoniated rice hulls, ammoniated sorghum stubble, raw sorghum stubble, ammoniated wheat straw, and raw wheat straw, respectively. The mean average difference between the predicted and actual fecal dry matter output was significantly different ($P < .01$) from zero. The low recovery rates could have possibly been due to method of feeding chromic oxide, to diurnal variation in excretion, to sampling procedures, or to chemical analysis.

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