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RH. Pritchard
South Dakota State University

A. N' Daiye
South Dakota State University

BEEF REPORT

EVALUATION OF AN ACID HYDROLYZED WOOD BY-PRODUCT AS AN ENERGY AND PROTEIN SOURCE IN RUMINANT DIETS

R. H. Pritchard and A. N'Daiye
Department of Animal and Range Sciences

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Summary

An acid hydrolyzed wood pulp (AHWP) product that had been buffered with NH_4OH was evaluated as a potential feedstuff for ruminant diets. The finely ground low dry matter (33%) material was evaluated for acceptability, digestibility and protein feeding value. In vitro fermentation indicated that fermentable dry matter was extremely low, 35.1%. Diets were not readily consumed by cattle if they contained >60% AHWP. In vivo dry matter digestibility (DMD) coefficients where AHWP replaced corn as 0, 15, 30 or 45% of the diet were 76.5, 69.3, 65.6 and 78.5%, respectively. A similar response was noted for crude protein and acid detergent fiber disappearance and indicated that negative associative effects due to forage:concentrate ratios may have existed. Nitrogen balance data indicated that the 16% crude protein AHWP contributed no useful dietary nitrogen.

(Key Words: Acid Hydrolyzed Wood Pulp, Dry Matter Digestibility, Dietary Nitrogen.)

Introduction

Some beef producing regions do not have ample feed grain supplies but do have lumber industries where excess sawdust is available to include in ruminant diets. This sawdust has a proximate feed value similar to wheat straw. Processing methods are being developed to improve the feed value of this material. We were interested in the opportunity to evaluate one of these processed products since similar technology may be useful in increasing our utilization of cereal grain residues in South Dakota.

The experimental product had been treated with sulfuric acid as part of the hydrolysis procedure done in another laboratory. On our request, ammonium hydroxide was incorporated into the material to simultaneously raise the pH and crude protein content for feeding (table 1). Our objectives were to find a suitable method for incorporating this material into diets and to determine its palatability and relative energy and protein feeding values for ruminants.

Materials and Methods

<u>Experiment I</u>. In vitro fermentable dry matter was evaluated by fermenting 750 mg samples when AHWP replaced 0, 20, 40, 60, 80 or 100% of the ground corn substrate. Forty-eight hour incubations were done in a medium of three parts buffer (Tilley and Terry, 1963) and two parts rumen fluid. Rumen contents were obtained via a permanent ruminal fistula in a steer fed alfalfa hay. Contents were squeezed by hand and the liquor was saved.

The liquor was then blended for 45 seconds and strained through four layers of cheesecloth before adding it to the in vitro system. At the end of the 48-hour fermentation, samples were immediately centrifuged for 20 minutes at 3000 x g and the supernatant was removed. The remaining pellet was dried at 65° C for 36 hours and was presumed to be nonfermentable dry matter. In vitro fermentable dry matter content of each sample was regressed against its AHWP content and the regression equation generated was used to define the in vitro fermentable dry matter (IVFDM) of AHWP and corn grain.

Experiment II. Six yearling beef heifers of mixed breeding were grouped as large framed and small framed types and assigned to diets containing 0, 30 or 60% AHWP. The objective was to determine if the material would be consumed and if it had any detrimental effects on bovine health or performance.

Diets shown in table 2 gradually replaced a standard maintenance diet over a 4-day period. During adaptation, dry matter intake was maintained at 5 $kg \cdot hd^{-1} \cdot d^{-1}$. On the fifth day dry matter offered was increased .75 kg daily until feed was refused. Orts were removed daily when necessary to assure fresh feed was available. This regimen was followed for 28 days. Initial and final weights of heifers were taken in the morning before feeding.

Experiment III. Sixteen Sixteen crossbred wether lambs were used to determine the effects of increasing proportions of AHWP on in vivo dry matter digestibility. Lambs previously treated for internal and external parasites, received injectable vitamins A, D and E and were group fed a maintenance diet (table 3).

Treatments included a control diet and three diets in which AHWP replaced 15, 30 or 45% of the corn in the control diet (table 4). Four individually fed lambs were assigned to each diet. Substitution of test diet for the maintenance diet occurred over a 4-day period. Lambs were fed test diets (750 g) for 11 days including 4 days in metabolism stalls before the digestion study began. Feces and urine were collected for 4 days. Intake was then raised to 1000 $g \cdot hd^{-1} \cdot d^{-1}$, maintained for 3 days and was followed by a second 4-day period of urine and feces collection.

Fecal samples were pooled within each 4-day collection period for each lamb and stored at 2° C. At the end of the collection period feces were mixed well, subsampled, dried and ground through a 1 mm screen for determination of dry matter (DM), nitrogen (N) and acid detergent fiber (ADF) content.

Urine output was collected in a vessel containing 100 ml of 30% HCl solution (v/v). Urine output of <1000 ml was diluted to 1000 ml with deionized water to avoid possible precipitate formation. Subsamples (10%) of urine output were pooled during each 4-day collection period for each lamb and stored at 2° C.

Feed and feces were dried in a forced draft oven at 100° C for 36 hours for DM determination.

Nitrogen content of urine, feed and feces was determined by the Kjeldahl method. Acid detergent fiber content of feed and feces was determined as described by Goering and Van Soest (1970).

There were no differences in variables measured attributable to collection period and no period x diet interactions existed. Therefore, period values were pooled and data analyzed as a completely random design experiment with subsamples.

Experiment IV. To determine the feed value of N added to AHWP as ammonium hydroxide, diets were formulated to contain 40% AHWP and 12, 14 or 16% crude protein. A control diet containing no AHWP and 12% crude protein was used for comparisons. These diets (table 5) were fed to 20 wether lambs previously group fed a maintenance diet (table 3) for 30 days to minimize animal differences.

Lambs were separated into five groups based on weight and one lamb from each of these groups was randomly selected for assignment to a dietary treatment. These diets were individually fed to lambs once daily for 30 days, including 5 days adaptation to metabolism cages.

Nitrogen balance collections were made over two consecutive 4-day periods. Urine was collected in acid, diluted when necessary and subsamples were pooled as described for Experiment III. A sample of each 4-day composite was then frozen for subsequent analysis. Feces were pooled for 4 days, mixed and subsampled. This subsample was dried in a forced draft oven at 65° C for 48 hours to determine DM content and to facilitate handling.

Dry grain portions of each diet were premixed in quantities sufficient to complete the experiment. This premix was mixed with AHWP daily to assure feed quality. During the collection period, 730 g diet DM were offered daily. Refusals were weighed back and included as part of the 730 g offered at the next feeding to minimize orts.

Data were analyzed as a completely random design with diet and replicate as main effects and replicate within diet variance used as the error term. Comparisons were made as follows: (1) control vs diets containing AHWP; (2) 12 vs 14 vs 16% crude protein diets compared by linear contrast; and (3) linear and quadratic response to crude protein only when diets contained AHWP.

Experiment V. Ten lambs that had been used in the previous experiment were used to determine effects of sustained feeding of diets containing AHWP and sawdust on dry matter intake, average daily gain and digestive organ integrity. Four lambs were fed a typical lamb diet. The remaining six lambs were fed a diet containing 40% AHWP and 20% sawdust. The composition of each diet is shown in table 6. The amount of control diet offered daily was restricted to the mean intake of lambs on the experimental diet.

Average daily gain and daily individual feed intake were monitored for 45 days. One lamb receiving the control diet and four lambs fed the experimental diet were maintained on these same diets for an additional 18 days before slaughter. Gross examinations of the gastrointestinal tract and internal organs of these five lambs were made and tissue samples from the proximal duodenum, distal ileum, kidney and pancreas were submitted for histological examination.

Results and Discussion

Experiment I. Regression analysis of the in vitro fermentable dry matter (IVFDM) data indicated that values for corn and AHWP were 83% and 35.1%, respectively. The depression in IVFDM as AHWP content of substrate increased was linear ($P<.05$; table 7).

Lab analysis (table 1) indicated that the AHWP was still primarily a fibrous material. Results of the in vitro fermentation suggest that the product is slowly degraded by ruminal microbes and that use as an energy source may be limited.

Experiment II. This trial was initially attempted with diets containing 0, 40 and 80% AHWP, but heifers refused to consume the 80% AHWP diet. Adaptation to the 30 and 60% AHWP diets was slow. Intake of the 60% AHWP diet remained markedly lower than the control diet (table 8). The depressed weight gain observed when feeding 60% AHWP was probably due to the reduced feed intake, since no detrimental effects on animal health and comfort were observed.

Experiment III. Utilization of N in AHWP was not known when this trial was conducted. To avoid crude protein limitations on dry matter intake and diet digestibility, a high level of soybean meal was included in each diet.

Intake of the diet containing 45% AHWP was low and forced restriction to 800 or 1000 g dry matter offered $hd^{-1} \cdot d^{-1}$. This level was slightly above maintenance and all lambs maintained a positive weight balance while housed in the metabolism stalls.

Apparent digestion coefficients are shown in table 9. Dry matter, crude protein and ADF digestibility were depressed when 30% AHWP was included in the diet. The proportion of digestible N retained was also lower. Poor diet digestibility probably resulted in inadequate energy for utilizing all of the N absorbed relative to the other diets.

Crude protein digestibility was closely tied to DM digestibility. Apparently the nonprotein N in the AHWP is tightly bound and released only when digestion of the AHWP occurs.

Coefficients of digestion for all variables were similar to or greater than those for the control diet when 45% AHWP was fed. It is possible that the depressed utilization of diets containing 15 or 30% AHWP may have been a response to roughage:concentrate levels in the diet. There appear to be negative associative effects on digestibility, especially fiber fractions, when diets contain ratios of 30:70 to 70:30 roughage to concentrate. In this study, if AHWP is considered a roughage, diets containing 0, 15, 30 or 45% AHWP would have roughage:concentrate ratios of 30:70, 45:55 and 75:25, respectively. Diets 15 and 30 then fall into the range of ratios that may have the poorest fiber digestion coefficients, as was actually the situation (table 9).

These data suggest that the greatest utilization of AHWP may be obtained by inclusion in high forage diets. Further evaluation with higher forage diets would be necessary to verify this relationship.

Experiment IV. Supplemental Supplemental crude protein appears critical when feeding AHWP. An initial effort to feed a diet formulated to contain 10% crude protein was unsuccessful. The crude protein of AHWP (11.75%) used in this trial was lower than the initial product, resulting in 8.7% CP diet. Crude protein levels this low can depress intake but should not result in the complete feed refusals encountered. The overestimation of AHWP crude protein content caused an overestimation of dietary crude protein for each treatment used in this trial but did not affect our ability to establish the nutritive value of AHWP nitrogen.

Increasing crude protein had a marked effect on DM intake (table 10). Lambs were offered 730 g DM daily, but at lower crude protein intakes significant refusals were recorded. Lowered intake associated with diets 12 and 14 was apparently not related to DM digestibility since all diets containing AHWP had similar DM digestibility coefficients.

Nitrogen digested, nitrogen retained and N retained as a fraction of N digested were lower for diets containing AHWP. Nitrogen digestibility was also lower for diet 12 than for diet 14. When considering only diets containing AHWP, supplemental crude protein caused a linear increase in dry matter intake ($P<.01$), N digestibility ($P<.001$) and N retention ($P<.05$).

By regressing the percentage supplemental crude protein in each diet against N retention, we can predict how much supplemental crude protein would be necessary to obtain N retention values similar to the control diet. This predictive relationship indicated that AHWP diets must contain 12.7% crude protein from supplemental sources to cause a similar amount of N retention as the controls. Since the control diet contained 11.9% crude protein, this value indicates that the N contained in the AHWP had no nutritive value.

Serum urea N concentrations were low for diets containing AHWP, indicating ruminal ammonia N and N availability were limiting. Serum urea N responded to supplemental crude protein in a linear fashion ($P<.05$) but never reached levels found when the control diet was fed.

Experiment V. Lambs Lambs were reluctant to consume diets at levels necessary for growth (table 11). Mean dry matter intakes were only slightly greater than 2% of body weight and were not sufficient to maintain body weight. Over the 45-day feeding period, live weight of lambs fed the AHWP-sawdust diets decreased from 35 to 31 kg. Control lambs fed a similar amount of dry matter gained 1.8 kg during this period.

These diets were high in crude protein (13%) but included only approximately 8.3% units as supplemental crude protein. Results of Experiment IV, which were not available when this trial was initiated, would indicate that higher levels of crude protein would be necessary to increase dry matter intake.

At slaughter the rumen of lambs fed AHWP diets differed in appearance from the control lamb. The rumen of lambs fed AHWP were full of wool. Wool biting was not severe since lambs were indvidually penned, but it obviously occurred and may reflect a need for additional dietary crude protein. The rumen epithelial tissue was blackened which is observed with some other feedstuffs. Papillae diameter, however, was dramatically reduced, and length and density of papillae appeared reduced compared to normal tissue.

Histological examination reflected that blunting of intestinal villi occurred in two individuals and was perhaps the only lower gut aberration that might be attributed to AHWP feeding. Case number 5 was the control lamb included in the slaughter comparison.

Conclusions

Chemical analysis indicates that treatments used to prepare the acid hydrolyzed wood pulp product have not significantly reduced the lignin and fiber components when compared to raw aspen sawdust. The procedure did reduce the sawdust to a paste form that was difficult to handle and should be blended with some type of large particle size dry material to become manageable. We stored the product under refrigeration at 2° C, but found it has a long shelf life when stored at 35° C.

The high acidity of the initial product would be very corrosive to feed handling equipment. Buffering the material with ammonium hydroxide reduced acidity and did not result in any detectable ammonia odor. Apparently the nitrogen added as ammonium hydroxide has complexed with the parent material in a very stable form. Digestion of this nitrogen appeared limited and it possessed no nutritive value. Dry matter intake responses would also indicate that the nitrogen content of AHWP should not be considered when formulating diets.

The quadratic response in dry matter and particularly acid detergent fiber digestibility observed in Experiment III suggests this feedstuff may be more valuable when added to high roughage diets. Negative associative effects and inadequate crude protein supplementation may have masked the full potential of this material in ruminant diets in these trials.

TABLE 1. COMPOSITION OF ACID HYDROLYZED WOOD PRODUCT

	Dry matter basis, %
Crude protein	16.7
Acid detergent fiber	46.8
Neutral detergent fiber	52.8
Total sugars, invert	33.9
Lignin	12.6
Dry matter[a]	33.0
pH	5.5

[a] As is basis.

TABLE 2. DIETS USED TO EVALUATE AHWP EFFECTS ON INTAKE BY HEIFERS[a]

Item	Treatment[b]		
	0	30	60
Cracked corn	80	50	20
AHWP	--	30	60
Corn cobs	14.17	13.74	13.30
Soybean meal, 44%	4.00	4.00	4.00
Dicalcium phosphate	--	.70	1.39
Limestone	1.03	.46	--
Trace mineral salt[c]	.30	.30	.30
Potassium chloride	.50	.80	1.10
Crude protein	10.53	10.51	10.50

[a] All values expressed as a percentage of diet dry matter.
[b] Treatment refers to percentage acid hydrolyzed wood pulp in the diet.
[c] Contains >94.5% NaCl, .007% I, .240% Mn, .240% Fe, .050% Mg, .032% Cu, .011% Co, .032% Zn, <.600% Ca.

TABLE 3. FEEDER LAMB RECEIVING DIET[a]

Item	%
Corn cobs	39.0
Cracked corn	42.5
Dehydrated alfalfa	10.0
Soybean meal, 44%	6.0
Dried molasses	1.0
Trace mineral salt[b]	.5
Dicalcium phosphate	1.0
Crude protein	9.75
ME, Mcal/kg	2.43

[a] Percent dry matter basis.
[b] Contains >94.5% NaCl, .007% I, .240% Mn, .240% Fe, .050% Mg, .032% Cu, .011% Co, .032% Zn, <.600% Ca.

TABLE 4. DIETS USED TO EVALUATE AHWP DRY MATTER DIGESTIBILITY IN EXPERIMENT III

Ingredient[a]	Diet 0	15	30	45
Soybean meal, 44%	11.26	11.26	11.26	11.26
Corn cobs	30.00	30.00	30.00	30.00
Cracked corn	57.56	42.56	27.56	12.56
AHWP	--	15.00	30.00	45.00
Limestone	.78	.78	.78	.78
Trace mineral salt[b]	.40	.40	.40	.40
Dry matter	93.3	76.0	62.5	54.4
Crude protein	12.84	13.25	13.44	13.60
Acid detergent fiber	19.1	25.8	34.8	48.4

[a] Percent of diet dry matter.
[b] Contains >94.5% NaCl, .007% I, .240% Mn, .240% Fe, .050% Mg, .032% Cu, .011% Co, .032% Zn, <.600% Ca.

TABLE 5. NITROGEN UTILIZATION STUDY DIETS, EXPERIMENT IV

Ingredient[a]	Diet 12	14	16	Control
AHWP	40.00	40.00	40.00	--
Corn cobs	25.00	25.00	25.00	25.00
Soybean meal, 44%	2.90	8.03	13.02	9.40
Cracked corn	30.12	25.21	20.55	64.22
Potassium chloride	.60	.46	.23	--
Dicalcium phosphate	.64	.50	.40	--
Trace mineral mix[b]	.50	.50	.50	.50
Limestone	.24	.30	.30	.88
Crude protein, %	9.7	12.1	13.5	11.9
Moisture, %	40.0	40.5	40.6	7.3

[a] Percent dry matter basis.
[b] Contains >94.5% Mcal, .007% I, .240% Mn, .240% Fe, .050% Mg, .032% Cu, .011% Co, .032% Zn, <.600% Ca.

TABLE 6. DIETS USED FOR DRY MATTER INTAKE COMPARISON, EXPERIMENT V

Ingredient	Control[a]	Experimental[a]
AHWP	--	40.00
Sawdust	--	20.00
Corn cobs	25.00	--
Cracked corn	25.00	27.22
Soybean meal, 44%	--	11.28
Alfalfa	40.00	--
Corn starch	7.65	--
Limestone	.20	--
Dicalcium phosphate	.85	.50
Potassium chloride	.80	.50
Trace mineralized salt[b]	.50	.50
Crude protein	11.5	13.0

[a] Percent dry matter basis.
[b] Contains >94.5% Mcal, .007% I, .240% Mn, .240% Fe, .050% Mg, .032% Cu, .011% Co, .032% Zn, <.600% Ca.

TABLE 7. IN VITRO FERMENTABLE DRY MATTER OF ACID HYDROLYZED WOOD PULP AND CORN MIXTURES, EXPERIMENT I

Treatment[a]	Mean values of IVDMD, %	Regression equations
0	79.85	
20	82.85[b]	$Y = 83.09 - .48X$
40	61.96[b]	$r^2 = .87$
60	48.26[b]	Y = IVFDM
80	41.00	X = % AHWP
100	40.32	
SEM	2.70	

[a] Treatment refers to percentage acid hydrolyzed wood pulp.
[b] Adjacent means in the same column differ ($P<.05$).

TABLE 8. INTAKE BY BEEF HEIFERS OF DIETS CONTAINING ACID HYDROLYZED WOOD PULP, EXPERIMENT II

Item	Treatment[a]		
	0	30	60
Initial weight, kg	361	336	350
Final weight, kg	413	393	371
Average daily gain, kg	1.85	2.00	.76
Daily dry matter intake, $kg \cdot hd^{-1} \cdot d^{-1}$	7.87	9.65	6.30
Feed/gain	4.26	4.88	8.29
Dry matter intake for last 7 d, $kg \cdot hd^{-1} \cdot d^{-1}$	9.73	9.90	6.10

[a] Treatment refers to percentage acid hydrolyzed wood pulp in the diet.

TABLE 9. MEAN VALUES OF DRY MATTER INTAKE, DIGESTIBILITIES OF DRY MATTER CRUDE PROTEIN AND ACID DETERGENT FIBER AND NITROGEN RETENTION, EXPERIMENT III

Diet[a]	Apparent digestibility			Nitrogen[b] retention
	Dry matter	Crude protein	Acid detergent fiber	
0	76.5[c]	81.7	49.5	85.4
15	69.3	78.2[d]	35.2	81.9[d]
30	65.6[c]	75.2[c]	33.0[c]	75.6[c]
45	78.5	85.3	73.4	83.7
SEM	3.5	7.1	5.6	3.5

[a] Diet refers to percentage acid hydrolyzed wood pulp.
[b] (Nitrogen retention ÷ N digested) x 100.
[c,d] Adjacent means in the same column differ ($^{c}P<.05$; $^{d}P<.10$).

TABLE 10. NITROGEN BALANCE OF LAMBS FED AHWP AND INCREASING LEVELS OF CRUDE PROTEIN, EXPERIMENT IV[a]

Item	Control	12	14	16	SEM
Dry matter intake, $g \cdot hd^{-1} \cdot d^{-1}$	73.0[b]	517[c]	621	715	36
Dry matter, digestibility, %	74.9[d]	67.0	65.3	65.3	1.58
Nitrogen intake, $g \cdot hd^{-1} \cdot d^{-1}$	55.8	31.7	47.9	61.7	2.1
Nitrogen digestibility, %	71.7[d]	58.7[e]	65.1	68.6	1.0
Nitrogen retention, $g \cdot hd^{-1} \cdot d^{-1}$	24.4[d]	5.5	10.3	15.0	.6
Nitrogen retained: nitrogen digested, %	60.6[d]	28.4[f]	32.4	35.0	6.2
Serum urea nitrogen mg/dl	12.4[d]	5.9[f]	6.9	9.5	.8

[a] Dry matter basis.
[b] Control differs from diets containing AHWP ($P<.05$).
[c] Linear effect of supplemental crude protein in diets containing AHWP ($P<.01$).
[d] Control differs from diets containing AHWP ($P<.001$).
[e] Linear effect of supplemental crude protein in diets containing AHWP ($P<.001$).
[f] Linear effect of supplemental crude protein in diets containing AHWP ($P<.05$).

TABLE 11. PERFORMANCE OF LAMBS FED AHWP BASED DIETS AD LIBITUM, EXPERIMENT V[a]

	Day			
Item	0	17	31	45
Wt, kg	35.2	33.6	34.0	31.1
As fed intake[b], g/d	--	1204	1408	1442
Dry matter intake[b], g/d	--	662	774	793
Dry matter intake/ weight, %	--	1.92	2.29	2.44

[a] n = 6.
[b] Intakes indicated are interim values.