Acid Hydrolyzed Wood Residue as an Ingredient in Ruminant Rations

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Story in Brief

The nutritive value of acid processed wood residues for ruminants was studied in 5 growth, performance and digestion trials with sheep and beef cattle.

Two materials were tested, LA-HWR which was processed at 0.8 percent H_2SO_4 and HA-HWR which was processed at 2.3 percent H_2SO_4. LA-HWR was highly palatable and had a dry matter digestibility of approximately 32 percent. This is sufficient to be encouraging as a potential source of energy for ruminants on maintenance levels of subsistence such as beef cows. HA-HWR was unpalatable and appeared to be considerably less digestible. Thus, the acid processing can be carried too far. Intermediate levels were not tested.

Introduction

Because of recent emphasis on the impact of pollutants on the environment, numerous efforts are underway to attempt to find economic uses for items one time discarded. If the pollutants are biodegradable, one might provide the best solution by developing means for accelerating this degradation. If the degradation can contribute to some economic enterprise as well, then society is benefited in two ways. Wood residues from lumber mills, pulping plants and paper factories represent an immense quantity of material for which disposal means are either lacking or prohibited.

The ruminant animal possesses a biodegradation capability in its rumen enabling it to economically utilize plant feedstuffs which are indigestible by other types of animals. Wood residues consist of complex cell wall carbohydrates similar to other plant feedstuffs but which are essentially undigestible in the ruminant because of the physical complexing with a material called lignin which prevents microbial attack on the carbohydrates. Attempts to solve this problem have involved chemical treatment to (1) remove the lignin or (2) hydrolyze the carbohydrate away from the lignin and produce a product in which the carbohydrate is digestible.

Although the former process is now known to be quite feasible, the economics of treating large quantities of material by this means are

with a mineral acid, appears to be more feasible economically but has not been studied as well. The objective of this study was to determine the nutritive value of acid hydrolyzed hardwood residues for ruminants.

Materials and Methods

The two products tested were produced by the Dierks Division, Weyerhaeuser Corp., Hot Springs, Ark. Mixtures of 4 parts hardwood to 1 part pine were coarsely ground. Low acid hydrolyzed wood residue (LA-HWR) was produced by treating the wood with 0.8 percent H_2SO_4 for 60 seconds at 600 p.s.i. High acid hydrolyzed wood residue (HA-HWR) was produced with 2.3 percent H_2SO_4 at the same pressure for 40 seconds. Both products were neutralized with anhydrous ammonia and allowed to "cook" in a closed room for 24 hours prior to being cooled to ambient temperatures. The products varied from 50 to 60 percent dry matter.

Trial 1

Thirty-four wether lambs were allotted to the 6 rations shown in Table 1. The basal ration was alfalfa meal and LA-HWR was substituted for 25, 50 and 75 percent of the alfalfa meal. In rations 2, 3 and 4; soybean meal (SBM) was added to make the rations have equal crude protein content. Rations 5 and 6 contained 50 and 75 percent LA-HWR without added SBM. All lambs were housed in individual pens and provided both feed and water free choice for 89 days.

Daily feed consumption was recorded and all animals were weighed at 2 week intervals. Feces were collected from all lambs for two 7 day periods during the trial to determine ration digestibilities. The feed and feces were analyzed chemically by routine procedures.

Trial 2

Thirty growing wether lambs were allotted to the rations shown in Table 3. In this trial HA-HWR was again substituted for alfalfa meal but due to the low palatability of this product, 35 percent was the highest level of substitution possible. Feces collections were again made at 2 times during the 90 day feeding period. Procedures for the growth trial and the digestion trials were the same used in trial 1.

Trial 3

This trial was conducted to determine the ability of hydrolyzed wood residue to support the growth and maintenance of beef steers. The rations as shown in Table 5 were designed to support a rate of gain typical of

Table 1. Composition of LA-HWR Rations and Performances of Lambs fed These Rations (Trial 1)

Item or measurement	1 Basal	2 25% LA + SBM	3 50% LA + SBM	4 75% LA + SBM	5 50% LA	6 75% LA
			% Composition, dry basis			
Alfalfa meal	99.5	70.6	40.5	11.1	48.7	23.0
LA-HWR	—	25.0	50.0	75.0	50.0	75.0
Soybean meal	—	3.9	8.2	12.4	—	—
T.M. salt	0.5	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	—	—	0.8	1.0	0.8	0.5
Vitamin D supp.	+	+	+	+	+	+
			Growth and Feed efficiency			
No. lambs	5	6	6	6	5	6
Ave. daily gain, lb.	.44[12]	.51[1]	.42[23]	.37[3]	.40[23]	.26[4]
Ave. daily DM consumption, lb.	3.12	3.98	3.78	3.87	3.61	3.19
DM intake per lb. gain, lb.	6.99[1]	7.90[1]	9.31[2]	10.37[3]	9.43[2]	12.60[3]
Non-wood DM intake per lb. gain, lb.	6.99[1]	5.93[1]	4.66[2]	2.59[3]	4.72[2]	3.15[3]

[1234] Means with unlike superscript are significantly different ($P<.05$).

Table 2. Coefficients of Digestibility for LA-HWR Rations (Trial 1)

Item	Apparent Digestibilities, %					
	Basal	25% LA + SBM	50% LA + SBM	75% LA + SBM	50% LA	75% LA
Dry matter	57.6[1]	51.2[2]	45.1[3]	38.8[4]	38.8[4]	36.8[4]
Organic matter	57.8[1]	50.8[2]	45.1[3]	38.4[4]	38.3[4]	36.4[4]
Cellulose	37.6	38.6	35.6	39.8	34.0	39.9
Nitrogen	61.2	59.3	59.3	58.4	51.3	45.4

[1234] Means with unlike superscript are significantly different ($P<.05$).

"wintering" rations. HA-HWR was substituted at the 20, 30 and 40 percent level. Twenty four steers were allotted by weight to the 4 rations groups and were self-fed the rations for 65 days. Two steers were removed from lot 2 for health reasons not associated with the rations. Eighteen hour shrunk weights were recorded every two weeks.

Table 3. Composition of HA-HWR Rations and Performance of Lambs fed These Rations (Trial 2)

Item or measurement	Basal	20% HA + SBM	35% HA + SBM	20% HA	35% HA
		% Composition, dry basis			
Alfalfa meal	99.5	73.3	52.8	79.5	64.0
HA-HWR	—	20.0	35.0	20.0	35.0
Soybean meal	—	6.2	11.5	—	—
T.M. salt	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	—	—	0.2	—	0.5
Vit. D supp.	+	+	+	+	+
		Growth and Feed efficiency			
No. lambs	6	6	6	6	6
Ave. daily gain, lb	.37[1]	.31[2]	.29[2]	.29[2]	.24[3]
Ave. daily dry matter consumption, lb	2.95	2.95	3.08	2.99	3.04
DM intake per lb gain, lb	7.97[1]	10.21[2]	11.50[23]	11.04[23]	12.16[3]
Non-wood dry matter per lb gain, lb	7.97	8.17	7.50	8.82	7.99

[123] Means with unlike superscript are significantly different ($P<.05$).

Table 4. Coefficients of Digestibility for HA-HWR Rations (Trial 2)

Item	Apparent Digestibility, %				
	Basal	20% HA + SBM	35% HA + SBM	20% HA	35% HA
Dry matter	54.8[1]	50.5[12]	45.7[34]	48.8[23]	43.2[4]
Organic matter	54.2[1]	50.1[12]	45.1[34]	48.4[23]	43.0[4]
Cellulose	42.4[1]	39.7[1]	29.6[2]	39.2[1]	42.2[1]
Nitrogen	56.6[1]	55.2[1]	51.9[12]	49.5[23]	46.0[3]

[1234] Means with unlike superscript are significantly different ($P<.05$).

Table 5. Composition of HA-HWR Steer Rations and Performance of Steers fed the Rations (Trial 3)

Item	1 Basal	2 20% HA	3 30% HA	4 40% HA
	% Composition, as is basis			
Alfalfa meal	99.5	68.4	55.6	44.6
HA-HWR	—	38.1	43.6	54.6
T.M. salt	0.5	0.5	0.4	0.4
Dicalcium phosphate	—	—	0.4	0.4
% Dry matter in feed	89.3	77.8	72.7	67.4
	Growth and performance			
No. steers	6	4	6	6
Ave. daily gain, lb	1.79	1.54	0.88	0.82
Ave. daily feed, lb. D.M.	15.6	16.6	12.8	12.7
Feed D.M. per lb gain, lb	8.7	10.8	14.5	15.5

Trial 4

The ability of HA-HWR to support the maintenance requirement of adult sheep was studied with 12 aged wethers allotted to three rations shown in Table 6. In this case cottonseed hulls (CSH) were used as the main component in the basal ration and HA-HWR was substituted for this ingredient. Using standard textbook values, a theoretical value for total digestible nutrients and digestible protein was calculated for each ration. The TDN value of HA-HWR was assumed to be 40 percent based on the previous experience with LA-HWR (this trial was conducted before the results of trials 2 and 3 were available). All sheep were then individually fed daily the amount of ration calculated to meet their maintenance requirement. Portions were recalculated as the weight of various sheep changed. All sheep were weighed weekly.

Trial 5

Digestibilities of rations similar to those used in trial 4 were determined using 6 aged wethers allotted to the three rations shown in table 7 in a 3 x 3 latin square design. During each period of the trial, the rations were fed for an 11 day preliminary adjustment and feces were collected over a 10 day period. Procedures for analyzing feed and feces were routine.

Results and Discussion

As the level of LA-HWR was increased in the ration, the growth rate of lambs decreased (Table 1). When SBM was included, however, the gains by lambs fed 25 and 50 percent LA-HWR were not signifi-

Table 6. Composition of Rations and Weight Changes of Aged Sheep on HA-HWR Maintenance Study (Trial 4)

Ingredient	1 Basal	2 25% HWR	3 50% HWR
	% Composition, dry basis		
Cottonseed hulls	80	55	30
HA-HWR	—	25	50
Cottonseed meal	9	9	9
Alfalfa meal	10	10	10
Minerals	1	1	1
	Maintenance data		
No. sheep	4	4	4
Ave. weight, lb			
5-18-71	124	126	124
6-10-71	123	119	116
6-24-71	126	120	111
7-8-71	127	121	110

cantly different from those fed the basal ration. Gains were lower, however when lambs were fed 75 percent LA-HWR with SBM or 50 and 75 percent LA-HWR without SBM. Daily consumption of ration dry matter was not decreased by the presence of LA-HWR.

Dry matter required per unit of gain was increased at all levels above 25 percent LA-HWR. The non-wood dry matter intake per unit of gain was calculated to determine if the wood material was being used for maintenance and growth. As shown in Table 1, as the level of LA-HWR increased, the amount of non-wood dry matter required per unit of gain decreased significantly. This is positive proof that the LA-HWR was indeed being utilized as an energy source.

Table 2 shows the digestibility coefficients for the LA-HWR rations. Both dry matter and organic matter digestibilities decreased as the level of LA-HWR increased in the ration. By using regression techniques, the dry matter digestibility of the LA-HWR component of the ration was calculated to be 32 percent. Although this may seem low, it is far better than the digestibility of the original wood material and approaches the digestibility of some low quality roughages. This supports the conclusion from the growth trial that the material was being partially utilized. Nitrogen digestibility was decreased in those rations not containing SBM so the high level of N provided by the anhydrous ammonia was apparently partially bound in a non-absorbable form.

The growth and performance of lambs fed HA-HWR are shown in Table 3 and the digestibilities of these rations are reported in Table 4. In contrast to the previous trial, lamb gains were depressed at all levels

of HA-HWR. Although daily feed consumption was not changed, the HA-HWR was obviously not being utilized for growth as indicated by the dry matter and non-wood dry matter requirements per unit of gain. Dry matter and organic matter digestibilities were sharply depressed by HA-HWR, considering the fact that the maximum level in the ration was 35 percent. Using regression techniques again, it was determined that the dry matter digestibility of HA-HWR was probably less than 10 percent. Cellulose and nitrogen digestibilities were apparently less than in LA-HWR also.

Trial 3 was designed to determine if HA-HWR could contribute to the energy requirements for maintenance and growth of beef steers. Their performance is shown in Table 5. As the level of HA-HWR increased up to 30 percent in the ration, the rate of gain decreased sharply, with gains at 40 percent about the same as at 30 percent. The 20 percent HA-HWR ration was actually consumed as well or better than the alfalfa meal ration but consumption of the 30 and 40 percent HA-HWR rations was depressed considerably. Feed required per unit of gain was higher for all HA-HWR rations.

When the weekly consumption of these rations was observed, it could be seen that consumption of the 30 and 40 percent HA-HWR rations was less than half of that for the first two rations during the first week. After that, consumption of the HA-HWR rations increased gradually but not sufficiently to support comparable gains. The animals in lots 3 and 4 all lost weight for the first 3 weeks before beginning to gain weight for the remainder of the trial.

In the maintenance study with CSH-HA-HWR rations (trial 4, Table 6), the weights of the sheep on the control ration did not change appreciably while those consuming 25 percent HA-HWR decreased only slightly in weight. Both these groups consumed all their allotted feed while those on 50 percent HA-HWR did not consume all their feed regularly, especially at the beginning of the trial. This third group lost weight at first but they seemed to stablize as consumption became more regular and the body weight to maintain decreased.

Digestibility of similar cottonseed hull–HA-HWR rations is shown in Table 7 (trial 5). Although digestibility of dry matter and organic matter decreased with increasing levels of HA-HWR, the decreases were not as severe as noted with alfalfa–HA-HWR mixtures in trial 3. In fact, N-digestibility actually increased with the addition of HA-HWR. The reasons for somewhat better performance when mixed with CSH as compared to alfalfa meal are not known.

Table 7. Composition and Digestibility of CSH-HA-HWR Rations (Trial 5)

Ingredient	1 Basal	2 25% HWR	3 50% HWR
	% Composition, dry basis		
Cottonseed hulls	75	50	25
HA-HWR	—	25	50
Cottonseed meal	14	14	14
Alfalfa meal	10	10	10
Minerals	1	1	1
	Apparent Digestibilities, %		
Dry matter	50	47	45
Organic Matter	50	47	44
Cellulose	49	53	51
Nitrogen	35	52	54

Conclusions

These results suggest that wood residues could be processed to produce a material having nutritive value for ruminants. The LA-HWR had a dry matter digestibility of 32 percent and was highly palatable. On the other hand, when the acid level during treatment was increased from 0.8 percent (LA) to 2.3 percent (HA), a product was produced which not only had a low apparent digestibility but was also quite unpalatable. Thus, the optimum treatment might have been somewhere in between these two acid strengths.

Other chemical analysis verified the fact that the changes produced by 2.3 percent acid were much more drastic than those produced at 0.8 percent. Although further work on this project is not presently underway, it would appear to be feasible to produce a product from woody material which could serve as a source of a part of the energy requirement of ruminants, especially those existing on maintenance level rations such as beef cows. Cursory examination of the economics of such an operation suggests the costs may be within reason but this has not been thoroughly researched.

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