FOREST PRODUCTS LABORATORY (Madison, Wis. 53705)
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
Approved Technical Article

ASPEN BARK AND PULP RESIDUE FOR RUMINANT FEEDSTUFFS[1,2,3]

P. R. Fritschel[4], L. D. Satter[4], A. J. Baker[5], J. N. McGovern[6],
R. J. Vatthauer[7] and M. A. Millett[5]

University of Wisconsin, Madison 53706; and U.S. Department of Agriculture, Madison 53705

SUMMARY

Five experiments were conducted to determine the feeding value for sheep and cattle of aspen bark and of aspen pulp mill fines, a by-product of an ammonia-base sulfite tissue mill. In experiment 1, three groups of 15 ewes each were fed either alfalfa hay or a ration containing 72.5% pulp fines, or a ration containing 72.5% aspen bark. Ewe and lamb performance was similar and satisfactory for all groups. In experiment 2, ruminal ingesta from four rumen fistulated ewes fed rations containing pulp fines or aspen bark had an average pH of 6.3. The molar percentages of ruminal acetate, propionate and butyrate were 71.0, 18.8 and 7.2.

In experiment 3, 20 crossbred steers, weighing an average of 223 kg, were divided into two groups, with the control receiving alfalfa haylage and hay and the experimental group receiving a ration containing 75% pulp fines. Average daily gain (kg/day), dry matter consumption (kg/day) and feed efficiency (kg feed DM/kg gain) during the 101-day trial for the control and treatment groups were 1.09, 8.50 and 7.8; and .45, 7.68 and 17.1, respectively. in experiment 4, nine Angus beef cows were offered a feed mix containing 83% pulp fines plus approximately 2 kg alfalfa hay in a 7-month field trial. The cows consumed the pulp fines readily, and performance was equal to that expected from cows fed conventional rations.

In experiment 5, pelleted feedlot starter rations containing either oat hulls or pulp fines were compared with corn silage as aids in switching cattle to high-grain finishing rations during the first 3 weeks of the feeding period. Measurements of body weight changes were highly variable, but daily gain averaged 1.38, .76, .74 and .63 kg/day for the corn silage, oat hull and two pulp fines treatment groups, respectively.
(Key Words: Bark, Wood Residue, Feedstuff, Paper Mill Residue.)

INTRODUCTION

Wood pulp and bark residues have been used as energy sources for ruminants during periods of critical feed shortages, but have never been generally recognized as alternatives for conventional feedstuffs under normal economic conditions (Scott *et al.,* 1969). Two relatively recent developments, however, have stimulated re-evaluation of these materials as alternative feedstuffs. First, increasing costs of pollution control have given impetus to the wood-using industry to find alternate ways of disposing of wood and pulp residues. The use of these residues for a ruminant feedstuff may alleviate the need for dispoal procedures that can be costly. Secondly, the dramatic increase in cost of conventional feedstuffs has stimulated interest in low-cost feed substitutes, particularly for animals kept at maintenance levels.

Some wood resiudes are equal to low- or

[1] Research supported by the College of Agricultural and Life Sciences, University of Wisconsin, Madison; U.S.D.A. Forest Service, Forest Products Laboratory, Madison; Proctor and Gamble Co.; and Consolidated Papers, Inc.

[2] Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product.

[3] The authors thank Dr. J. R. Andersen for his cooperation in providing animals for one of the experiments, Mr. Leo Brunker for his contributions as herdsman in all of the experiments involving sheep, and Mr. Gary Fritz for his effort in gathering data in one of the experiments.

[4] Department of Dairy Science, University of Wisconsin, Madison.

[5] Forest Products Laboratory. The laboratory is maintained at Madison (N. Walnut Street, 53705) in cooperation with the University of Wisconsin, Madison.

[6] Department of Forestry, University of Wisconsin, Madison.

[7] Department of Meat and Animal Science, University of Wisconsin, Madison.

average-quality hay in terms of digestibility (Baker *et al.*, 1975) and perhaps could be substituted for forages, particularly in the rations of beef cows or ewes which are at a maintenance level of productivity for much of the year. The following experiments were conducted to test the feasibility of substituting pulp fines or aspen bark for as much as 70% of conventional feedstuffs in sheep and cattle rations.

METHODS AND PROCEDURES

Experiment 1. Forty-five pregnant 5- to 6-year-old western whiteface ewes were divided into three groups of 15 each. Each group was fed one of the rations shown in table 1. Two wood residues were examined. One was aspen bark; the other was unbleached aspen sulfite pulp fines composed mostly of parenchyma cells. Rations 1 and 2 were pelleted, and ration 3 (the control) was fed as long hay.

Rations 1 and 2 were fed *ad libitum* during the first 7 months of the experiment, then were restricted. Ration 3 was restricted, except during lactation, to prevent excessive weight gain. The amount of rations 1 and 2 was adjusted so that little or no feed was carried over from one feeding to the next. The ewes were fed twice daily for the duration of the 11-month experiment. A grain mix containing 43% each of ground shelled corn and ground oats and 14% soybean meal was fed at the rate of .45 kg daily to ewes during the last month of pregnancy and through the first 2 months of lactation, at which time the lambs were weaned.

Ewes were weighed monthly, and lamb performance through weaning was observed. The ewes were bred in October and November after having been fed rations containing the wood residues for approximately 10 months.

Experiment 2. Four rumen fistulated ewes were divided into two groups of two and fed twice daily either ration 1 or 2 as shown in table 1. Each ewe consumed 2.5 kg of air-dry feed daily. Rumen ingesta samples were obtained after the ewes were fed the experimental rations for a period of not less than 10 days. Sampling was on 2 consecutive days at 0, 1, 2, 3, 4, 6 and 8 hr after feeding. The rations fed to each group were switched, and following a 10-day adjustment period were sampled for ruminal ingesta as before. Ingesta pH was determined at the time of sampling. Ingesta samples were acidified and prepared for ammonia (Bremner and Keeney, 1965) and volatile fatty acid determinations (Baumgardt, 1964; Fenner and Elliot, 1963).

Experiment 3. Twenty crossbred Angus-Hereford steers weighing 223 kg were divided into two groups of 10 steers each. The control group was fed *ad libitum* a ration of high-quality alfalfa haylage plus .9 kg of alfalfa per day. The experimental group was fed *ad libitum* a ground, unpelleted ration containing 75% pulp fines (table 1, ration 4). Trace mineralized salt was available free choice to both groups. The experiment lasted 101 days. A 2-week pre-experimental period was allowed for the animals to adjust to the rations. Steers were weighed on 3 consecutive days to establish initial and final body weights.

Experiment 4. A small field trial with nine Angus beef cows was conducted to further evaluate pulp fines as a source of energy for ruminants. The trial was conducted through the winter and early summer (December 1 to July 2). The cows had access to a shed, which was open on one side. Feed intake was approximated by periodic weighing of a daily allotment of feed. Cows were offered daily 2 kg of alfalfa hay and 5 kg of ration 5 (unpelleted) shown in table 1. After April 1, hay was reduced to 1.4 kg per day. Three of the cows were pregnant at the start of the experiment, and calved during the trial. After calving the cows were fed once daily approximately 2.3 kg of a corn-wheat bran-soybean meal grain mix and 3.6 kg each of alfalfa hay and ration 5. Body weights were obtained at the beginning and end as well as periodically throughout the trial.

Experiment 5. The specific objective of this experiment was to compare pelleted feedlot starter rations containing either oat hulls or pulp fines as diluents of digestible energy in high-grain rations. These two roughage sources were compared to corn silage during the first 3 weeks of the feedlot period as aids in adjusting cattle to high-grain finishing rations. Forty Hereford steers averaging 383 kg were randomly assigned to four treatments, five steers per lot and two lots per treatment.

Treatment 1 served as the control group, and these steers were offered only corn silage during the first week. Shelled corn was introduced on day 8 and was increased at the rate of .25% of body weight every third day beginning on day 8. Soybean meal in the amount of .55 kg per head daily was offered during the 3-week

TABLE 1. RATION COMPOSITION (EXPERIMENTS 1, 2, 3 AND 4)

Ration ingredient	Ration 1 (Exp. 1)	2 (Exp. 1–2)	3 (Exp. 1)	4 (Exp. 3)	5 (Exp. 4)
	%				
Alfalfa, hay, s-c, early bloom (1)	...	...	100	...	...
Pulp fines[a]	72.5[c]	...	...	75.0[d]	83[e]
Aspen bark[b]	...	72.5[c]	...	...	...
Alfalfa, aerial part, dehy. (1)	7.5	7.1	...	5.0	...
Corn, yellow, grain, ground (4)	7.0	7.0	...	5.6	5
Oats, grain, ground (4)	5.0	5.0	...	7.0	5
Soybean, seeds, solv.-extd., ground mx 7% fiber (5)	5.0	5.0	...	3.0	4
Urea	1.5	1.5	...	2.5	1.5
Trace mineral salt[f]	.5	.5	...	.5	.5
Calcium phosphate, dibasic, commercial (6)	.5	.5	...	.5	.5
KCl[g]	.35	.35	...	.5	.3
Na_2SO_4	...	.40	...	...	...
Vit. ADE premix[h]	.15	.15	...	.15	...
Methionine hydroxy analog	500 g/ton	500 g/ton	...	...	...
Avg dry matter	85.9	81.7	87.9		
Avg crude protein	11.4	12.7	18.6		

[a]Aspen sulfite parenchyma cells (unbleached) from an ammonia base sulfite tissue mill. Furnished by Charmin Paper Company (Division of Proctor and Gamble). Green Bay, Wis. On a dry matter basis, the pulp fines contain: 70% carbohydrate, 20% lignin, 5% ether extract, 3% ash and 2% crude protein.

[b]Aspen bark furnished by Consolidated Papers, Inc., Wisconsin Rapids, Wis. On a dry basis, the bark contains: 53% carbohydrate, 29% lignin, 7% ether extract, 4.5% ash and 1.5% crude protein.

[c]Dry matter content of pulp fines and bark normally vaned between 75 and 85%. On dry basis, wood residues constituted approximately 67 to 70% of ration.

[d]Dry matter content of pulp fines averaged about 80%. On dry basis, pulp fines constituted 70 to 72% of ration.

[e]Dry matter content of pulp fines normally varied between 75 to 85%. On dry basis, pulp tines constituted approximately 80 to 82% of mixture.

[f]Contained 97% NaCl, .2% Mn, .3% Fe, .033% Cu, .007% 1 and .005% Co.

[g]The pulp fines and aspen bark contained approximately .1 and .2% potassium.

[h]Supplied 3,300 IU of vit. A and D and trace amounts of vit. E per kilogram of mixed feed.

TABLE 2. RATION COMPOSITION (EXPERIMENT 5)

Ration ingredients	Week of experiment	Treatment 2			Treatment 3			Treatment 4		
		1	2	3	1	2	3	1	2	3
		% composition								
Corn, yellow, grain ground (4)		31.1	53.6	69.6	22.6	48.3	68.0	26.1	50.0	68.0
Oats, grain, ground (4)		7.0	...	...	7.0	...	...	7.0	...	...
Alfalfa, aerial part, dehy. (1)		10.0	5.0	...	...	...	...	10.0	5.0	...
Oats, hulls (1)		40.0	29.0	15.0	...	...	...	...	...	...
Pulp fines[a]		...	...	...	50.0	34.0	15.0	40.0	29.0	15.0
Sugarcane, molasses, dehy. (4)		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Soybean, seeds, solv.-extd., ground mx 7% fiber (5)		3.0	3.0	6.0	11.5	8.3	7.6	8.0	6.6	7.6
Urea (281% CP)		1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Limestone, ground (6)		.5	1.0	1.0	.5	1.0	1.0	.5	1.0	1.0
Calcium phosphate, dibasic, commercial (6)		.5	.5	.5	.5	.5	.5	.5	.5	.5
Trace mineral salt[b]		.7	.7	.7	.7	.7	.7	.7	.7	.7
Pellet binder[c]		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vit. ADE premix[d]		.1	.1	.1	.1	.1	.1	.1	.1	.1
Dry matter (%)		90.0	90.4	90.7	88.4	88.8	89.2	87.9	88.0	90.9
Crude protein (% DM basis)		15.8	13.5	11.1	14.1	14.5	15.7	15.0	14.6	13.9
Crude fiber (% DM basis)		12.3	10.1	7.1	30.7	21.3	9.9	26.5	18.9	10.7

[a]See table 1, footnote a.

[b]See table 1, footnote f.

[c]Lignin sulfonate product with trade name of Dura-Bond.

[d]See table 1, footnote h.

0period.

Treatment groups 2, 3 and 4 were fed complete pelleted rations, the compositions of which are shown in table 2. Group 2 was fed oat hulls as the diluent for digestible energy. Rations fed during the first, second and third weeks in the feedlot contained 40, 29 and 15% oat hulls, respectively. Groups 3 and 4 were fed pulp fines as the diluent for digestible energy. Rations fed group 3 during the first, second and third weeks in the feedlot contained 50, 34 and 15% pulp fines, respectively. while rations fed group 4 contained a small amount of dehydrated alfalfa in addition to 40, 29 and 15% pulp fines, respectively. Therefore, treatments 2, 3 and 4 each consisted of a series of three rations. Each ration in a series was fed for 7 days, starting with the rations highest in crude fiber within each series. This resulted in approximately a 30%) sequential reduction in ration crude fiber.

Steers were implanted with 30 mg diethylstilbestrol before placement on the experiment. Initial and final body weights were the average of two consecutive daily weights following a 12-hr feed and water withdrawal period.

RESULTS AND DISCUSSION

Experiment 1. Data for average daily dry matter intake for each month of the experiment is shown in figure 1. There was little difference between the pulp fines and the aspen bark for animal acceptability. Both rations were readily consumed. Feed intake of the hay-fed

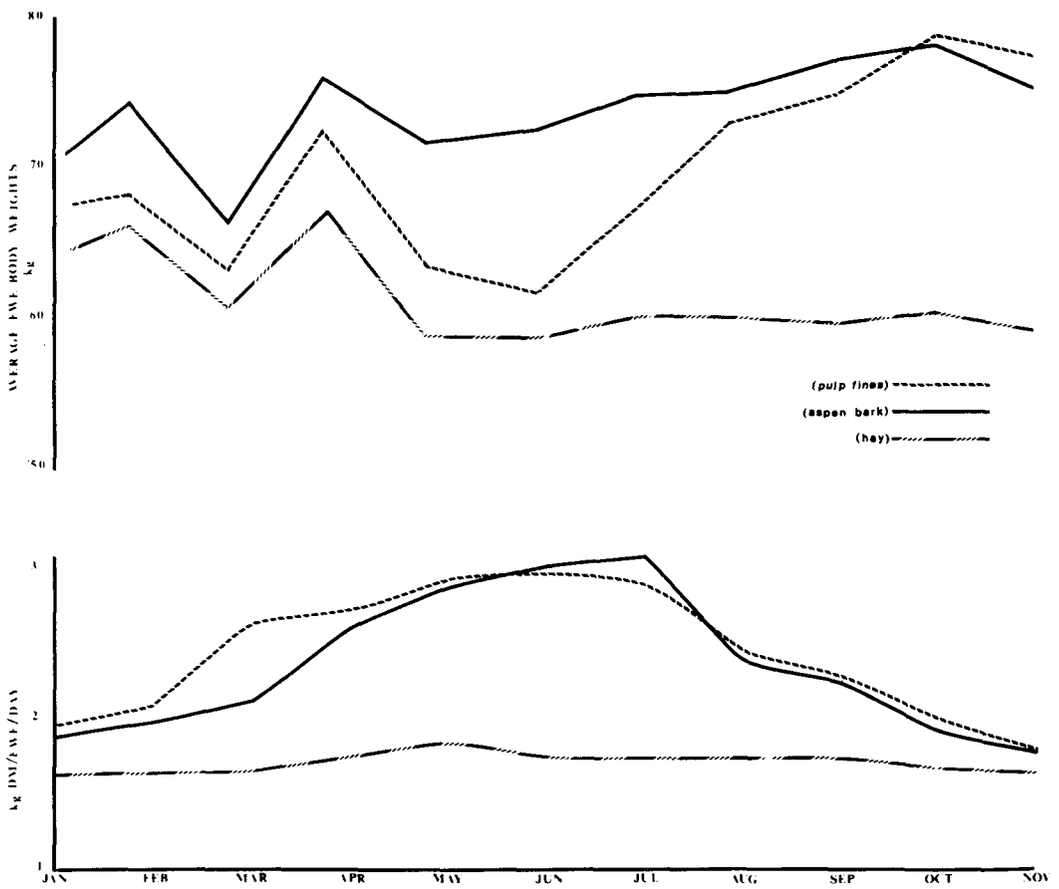

Figure 1. Average dry matter intake and body weight of ewes fed rations containing pulp fines, aspen bark or hay. Dry matter intake values are exclusive of grain consumption. Grain consumption was equal among all groups, and was in addition to the dry matter consumption shown above. Schedule of grain dry matter consumption in kg/ewe/day is as follows: March 7 to 9-.2; March 10 to April 22-.41; April 23 to 29-.49; April 30 to May 13-.52; May 14 to 29-.41. The abrupt loss of weight in February was due to shearing of wool, and in April to lambing.

control group was limited, and would have been greater under *ad libitum* feeding. Feed consumption was restricted for all groups from August until the end of the experiment to prevent excessive weight gain. Total dry matter intake of the hay-fed control group was approximately 70% of the two groups fed wood residues.

Ewes fed either pulp fines or bark had moderate gains in body weight over the entire experiment. Ewes fed hay actually lost a small amount of body weight, but that was probably due to underfeeding of hay (figure 1).

The number of lambs weaned per ewe in the pulp fines, aspen bark and hay-fed groups averaged 1.2, 1.3 and 1.0, respectively, and average weaning weights were 24.0, 23.0 and 23.0 kg, respectively.

One ewe from the group fed pulp fines died from an unknown cause, and one ewe from the hay-fed group died from pneumonia. Aside from these deaths, there were no apparent health problems. All of the ewes fed wood residues were bred and confirmed pregnant in October and November after having been fed the residues for nearly 1 year.

Experiment 2. Rumen pH and total volatile fatty acid concentration for the ewes fed pulp fines and aspen bark were 6.2 and 6.4 and 12.0 and 13.8 meq/liter, respectively. The molar percentages of acetate, propionate and butyrate were similar between groups, and averaged 72, 19 and 8%. The concentration of ruminal ammonia nitrogen was about 20 mg/100 ml rumen fluid, suggesting that some of the urea could be removed from the ration without any adverse effect (Satter and Slyter, 1974).

Experiment 3. Data for growth rate, feed consumption and feed efficiency for steers fed either haylage and hay or a ration containing 75% pulp fines are in table 3. Initial weight of the steers averaged about 223 kilograms. Steers fed the pulp fines gained .45 kg per day in contrast to 1.09 kg per day for the control group. Dry matter consumption was slightly less for the ration containing pulp fines, but utilization of feed was much better for the control group. The control group required 7.8 kg of feed dry matter per kilogram body gain, whereas the pulp fines group required 17.1 kilograms.

The alfalfa haylage fed to the control group was of high quality, and performance was exceptionally good. Performance of the group fed pulp fines was expected to be lower than for the control group, but the large difference in feed utilization was surprising. *In vivo* dry matter digestibility of pulp fines is about 50%, whereas the *in vitro* estimates of dry matter digestibility are closer to 70% (Millett *et al.*, 1973). The *in vitro* estimates of digestibility were done on pulp fine samples that were not exposed to heat, whereas fines used in the feeding trials were exposed to hot drying temperatures at the paper mill. Additional *in vitro* dry matter digestibility tests on air-dried fines and fines that were dried at 105 C for 18 hr have indicated that approximately half of the differences between *in vitro* and *in vivo* digestibility estimates could result from high-temperature drying conditions. The rest of the differential might be attributed to small particle size and a consequent rapid rate of passage out of the rumen. The large difference in feed efficiency between the two groups suggests that both digestibility and efficiency of digestible energy utilization must have been markedly lower for the group fed pulp fines.

The group fed pulp fines exhibited a craving for roughage, and it was necessary to use wood shavings for bedding to prevent consumption of bedding material. The short fiber length of the

TABLE 3. GROWTH RATE AND FEED CONSUMPTION OF STEERS FED ALFALFA HAYLAGE OK PULP FINES (EXPERIMENT 3)

Measurement	Control (haylage + hay)	Experimental (pulp fines)
Initial weight (kg)	226.6 ± 10	220.7 ± 16
Final weight (kg)	336.2 ± 16	266.5[a] ± 22
Gain (kg/day)	1.09 ± .11	.45[a] ± .10
Dry matter consumption (kg/day)	8.50	7.68
Feed efficiency (kg feed DM/kg gain)	7.8	17.1

[a]Significant treatment effect at $P<.005$.

TABLE 4. BODY WEIGHTS OF ANGUS COWS FED A RATION CONTAINING PULP FINES (EXPERIMENT 4)

Cow identification	Cow age	Body weight[a]					Reproductive status
		Dec. 1	Dec. 20	Jan.	Mar. 27	July 2	
	months	kg					
389	48	538	530	537	555	473	Calved Apr. 9
33	82	418	418	425	. . .	402	Calved May 8
369	49	499	500	515	545	501	Calved May 24
24	16	312	313	310	337	337	Bred Jan. 5
651	27	379	383	385	415	449	Bred Jan. 19
821	25	389	377	374	400	426	Bred Feb. 11
309	50	401	395	391	427	425	Bred Apr. 24
640	41	348	339	339	357	338	Open
23	16	298	306	306	326	335	Open

[a]Experiment started on December 1, and was terminated on July 2.

pulp fines provides little stimulus to rumination, and it would appear very desirable to include a minimum of 1 to 2 kg of long hay in the ration. This might have the beneficial effect of not only reducing the restless craving for roughage, but may also tend to increase the retention time of the pulp fines within the rumen.

The small particle size of the pulp fines made this ration dusty, and may have reduced animal acceptability of the ration. Rations containing pulp fines can be successfully pelleted, and this would do much to minimize dust problems.

Experiment 4. Acceptance of the pulp fine mixture was good, and no adverse reactions to the ration were observed. Observation of feeding behavior indicated that the cows consumed the mixture of pulp fines as readily as the hay when 2 kg of hay were offered. When only 1.4 kg of hay were provided daily, there appeared to be a preference for the hay. Two kilograms of hay seemed to alleviate the craving for roughage.

The three calves born during the trial had an average birth weight of 35 kg, and had an adjusted 205-day weight of 245 kilograms. The three cows were successfully bred back at about 3 months post-calving. Four of the remaining six cows were bred during the trial, and two remained open, but were bred within 30 days after the experiment terminated. Cow weights, ages and reproductive status are shown in table 4. The cows gained a moderate amount of weight during the trial.

One week was allowed as a transition period to get the cows started on the new ration. Occasionally, a cow would choke and cough at the onset of eating, apparently from insufficient wetting of the dry pulp fines mixture. The cows adapted quickly to the pulp fines mixture, and eagerly consumed it. There was no scouring or sickness. Rumination time was not measured, but casual observation indicated infrequent rumination.

Experiment 5. There has been an increase in recent years in the use of complete pelleted starter feeds for feeder cattle. These rations have been used as transition rations for feeder cattle previously fed grass or forage but which are not ready for high-grain finishing rations. Commercial feed mills have a problem obtaining fibrous feedstuffs that are suitable for processing in bulk through a mill operation. Corn cobs and oat hulls have been used for this purpose. Pulp fines appeared to present a potential alternative to these materials.

Weight change as an indicator of growth is highly inaccurate when measured over a period as short as 3 weeks. Small differences in reticulo-rumen fill can have a major influence on the calculated growth rate. Consequently, large variance in weight gain was encountered within as well as between treatment groups.

As shown in table 5, the control group fed corn silage gained an average of 1.38 kg per day, whereas those fed oat hulls (treatment 2) and pulp fines (treatments 3 and 4) gained .76, .74 and .64 kg per day, respectively. Total dry matter consumption was highest for the control group (1 1.9 kg/head/day), and was nearly equal for treatments 2, 3 and 4 (9.8, 10.3 and 9.0

TABLE 5. WEIGHT GAIN AND FEED CONSUMPTION OF FEEDER STEERS FED STARTER RATIONS CONTAINING CORN SILAGE, OAT HULLS OR PULP FINES (EXPERIMENT 5)

Measurement	Treatment			
	1 (corn silage)	2 (oat hulls)	3 (pulp fines)	4 (pulp fines)
Initial weight (kg)	388.6 ± 21	382.0 ± 20	382.6 ± 21	380.3 ± 24
Final weight (kg)	417.6[a] ± 21	397.9[b] ± 19	398.2[b] ± 24	393.7[b] ± 24
Gain (kg/day)	1.38[a] ± .27	.757[b] ± .84	.743[b] ± .61	.638[c] ± .55
Dry matter consumption (kg/day)	11.9[a]	9.8[b]	10.3[b]	9.0[c]
Feed efficiency (kg feed DM/kg gain)	8.6	12.9	13.9	14.1

[a,b,c]Values with unlike superscript letters differ significantly at $P<.05$.

kg/head/day, respectively). It required 8.6, 12.9, 13.9 and 14.1 kg feed DM/kg live weight gain for treatments 1, 2, 3 and 4, respectively.

After the 3-week experiment, animals were regrouped and assigned to a separate experiment involving a high-grain finishing ration. Analysis of the second experiment indicated no carryover treatment effect from the first study.

The steers readily consumed all rations. The pulp fines appeared to equal oat hulls as a diluent or source of fiber early in the feeding period. It would be very important to know the extent to which reticulorumen fill was influencing final steer weights. If anything. the pulp fines might be expected to have a relatively rapid rate of passage due to their short fiber length. This would tend to reduce reticulorumen fill, resulting in an underestimate of actual growth. Without measurements, however, this question remains speculative. In terms of animal acceptance and health, pulp fines appear suitable as a roughage substitute early in the feeding period. Growth rate appeared lower, however, when either oat hulls or pulp fines were fed.

It appears from this group of studies that ewes and beef cows, both of which were essentially in a state of maintenance, effectively utilized the wood residues. The performance of growing animals, however, was markedly poorer when the wood residues were substituted for alfalfa or grain in the ration. The generally lower nutritive value of wood residues suggests that they can best be utilized by animals having low nutritive requirements, such as ewes or beef cows.

LITERATURE CITED

Baker, A. J., M. A. Millett and L. D. Satter. 1975. Wood and wood-based residues in animal feeds. *In* A. F. Turbak (Ed.) Cellulose Technology Research. American Chemical Society, Washington, D.C.

Baumgardt, B. R. 1964. Practical observations on the quantitative analysis of free volatile fatty acids (VFA) in aqueous solutions by gas-liquid chromatography. Wis. Agr. Exp. Sta., Dairy Science Dept. Bull. 1, Univ. of Wisconsin, Madison.

Bremner, J. M. and D. R. Keeney. 1965. Steam distillation methods for determination of ammonium, nitrate and nitrite. Anal. Chim. Acta. 32:485.

Fenner, H. and J. M. Elliot. 1963. Quantitative method for determining the steam volatile fatty acids in rumen fluid by gas-liquid chromatography. J. Anim. Sci. 22:624.

Millett, M. A., A. J. Baker, L. D. Satter, J. N. McGovern and D. A. Dinius. 1973. Pulp and

papermaking residues as feedstuffs for ruminants. J. Anim. Sci. 37:599.

Satter, L. D. and L. L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production *in vitro*. Brit. J. Nutr. 32:199.

Scott, R. W., M. A. Millett and G. J. Hajny. 1969. Wood wastes for animal feeding. Forest Prod. J. 19:14.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1976-650-517/62