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Introduction

Aspen (Populus tremuloides), covering in excess of 58,000 acres in the Black Hills area and over 3 million acres in the Upper Great Lakes area, has not been harvested in sufficient amounts to perpetuate growth. Periodic harvesting is not only necessary to assure an aspen stand but younger trees are needed as a source of food for grouse, deer and other wildlife. Although aspen serves as a source of fiber for paper, lumber, insulation and other industrial uses, it is presently not used for these purposes in the Black Hills region. In all regions where aspen grows whether or not it has other uses, substantial stands have reached maturity (60 to 70 years old) and will die without production of replacement trees if harvesting programs are not initiated. South Dakota Department of Game, Fish and Parks is beginning such a program. In 1974 they were faced with the problem of utilization of harvested aspen trees. The purpose of this study was to determine the level at which the harvested aspen material could be fed to ruminants if corrected for known nutrient deficiencies such as protein and vitamin A. Of the hardwoods, aspen wood appears to have potential as a ruminant feed because of its low lignification (encrustation of fibers) and lack of known toxic constituents.

Materials and Methods

Approximately five acres of mature aspen were harvested near Sturgis, South Dakota, by the Department of Game, Fish and Parks consistent with accepted habitat improvement methods. The entire tree, including all branches, leaves and bark, was fed into a chipping device and blown into trucks for transporting to a drying bin near Egan, South Dakota. The dried chips were hammer-milled and directly incorporated into a complete pelleted ration. A ration containing 93% alfalfa served as the control. Five other rations were formulated using increasing levels of aspen at 12, 24, 32 and 48% of the total ration with the 48% level also being fed with 4% sodium hydroxide. Soybean meal (44% protein) was included in rations which contained aspen in a ratio of 40% soybean meal to 60% aspen. This ratio of soybean meal and aspen was used so that a soybean-aspen mix would approximate the alfalfa used as the control. The alfalfa used in this experiment contained 15% protein and the aspen material about 1% protein. Aspen material and soybean meal combinations then were used to replace 20, 40, 60 and 80% of the alfalfa in the control ration. All rations contained dried molasses, trace mineral salt, dicalcium phosphate and vitamin A. Four percent sodium hydroxide was added to one 48% aspen ration as a delignifying agent for aspen material. The ingredient composition is shown in table 1.

Table 1. Ration Composition, %

Ingredients	Control	12% aspen	24% aspen	36% aspen	48% aspen	48% aspen 4% sodium hydroxide
Alfalfa	93	73	53	33	13	13
Soybean meal	--	8	16	24	32	32
Aspen material	--	12	24	36	48	48
Molasses	5	5	5	5	5	5
Trace mineral	1	1	1	1	1	1
Dicalcium phosphate	1	1	1	1	1	1
Vitamin A[a]						
Estimated crude protein	14.88	15.20	15.52	15.84	16.16	16.16

[a]2,000 IU vitamin A per kg of ration.

Sixty Hereford steers weighing approximately 725 lb. were randomly allotted into 12 pens of 5 animals each. Each of the 6 rations was fed to 2 pens or 10 animals for a period of 93 days. All rations were fed as a complete pelleted ration on an ad libitum basis. Prior to the trial, animals were restricted to a ration of medium to poor quality mixed hay with no supplementation for a 3-week period. Animals were allowed approximately a 2-week period to reach full feed once the trial began. Animals were gaining about 0.5 lb. per day at this time. All experimental rations were well accepted and no intake problems were noted. Some difficulty was experienced in getting animals on full feed in one pen (5 animals) with the pelleted alfalfa control rations. Animals were off feed for a period of 2 days. Animals on all rations were fed an initial feed of 10 lb. per day and were increased by 10 lb. increments each day until full feed was achieved. Animals were weighed initially and at 32, 57 and 93 days. Initial and final shrunk weights were also obtained.

The amount of aspen available was sufficient to feed the steers for a period of 93 days. At this time, two steers from each pen (4 per treatment) were slaughtered for carcass data and taste panel evaluation of the meat. One steer from each pen (2 per treatment group) was used to conduct digestion and balance studies with the feedlot rations. The remaining 12 steers then were offered a high-concentrate finishing ration to determine effects of the previous experimental rations on later performance when fed typical high-concentrate finishing rations.

Results and Discussion

Growing and Finishing--Aspen Wood Phase

Feedlot Performance. Results of the 93-day feeding trial are shown in table 2. Differences between final filled and shrunk weights show a large amount of shrink (38 to 48 lb. per head) but with no apparent trend related to ration differences. Steers fed the control pelleted ration made a rather low rate of gain during the first 32 days of the experiment. Increasing

levels of aspen with the soybean meal resulted in improvements in weight gains up to the level of 32% aspen and 24% soybean meal. The alfalfa in all rations was prepared from previously pelleted alfalfa and reground to prepare complete pelleted feed in each treatment. The alfalfa, having been ground twice in ration preparation, was quite fine and may have contributed to unusually low weight gains for the high alfalfa control during the first 32 days. The coarser aspen rations appeared to assist in getting animals to full feed sooner. After the first month weight gains were improved for the alfalfa control group. The average gain of 1.87 lb. daily for the remainder of the 93-day experiment more nearly represents expected gains from feeding pelleted alfalfa to cattle of the weight used in the experiment. In contrast to the increased weight gain for the alfalfa control group, steers in all groups fed soybean meal and aspen replacing various amounts of the alfalfa showed lower weight gains after the first month as the animals became heavier. Weight gains at 93 days would be influenced by differences resulting during any previous weight period.

Table 2. Feedlot Performance as Affected by Aspen Content of Diets

	Treatments					
Item	Control	12% aspen	24% aspen	36% aspen	48% aspen	48% aspen 4% sodium hydroxide
Number of animals	10	10	10	10	10	10
Number of days fed	93	93	93	93	93	93
Avg. initial filled wt., lb.	728	728	723	726	725	726
Avg. final filled wt., lb.	873	934	980	989	978	970
Avg. initial shrunk wt., lb.	708	705	702	702	704	704
Avg. final shrunk wt., lb.	826	893	937	951	930	931
Avg. daily gain, lb.						
32 days (filled)	0.94	1.48	3.16	3.56	3.27	3.63
57 days (filled)	1.69	2.90	3.52	3.32	3.17	3.16
93 days (filled)	1.55	2.23	2.77	2.83	2.72	2.62
93 days (shrunk)	1.26	2.02	2.53	2.68	2.42	2.44
Avg. daily ration, lb.						
32 days (consumption)	16.49	19.03	23.75	24.42	23.25	23.71
57 days	21.38	24.46	28.56	29.40	26.14	27.42
93 days	24.68	27.74	30.33	30.86	27.81	29.09
Feed/lb. gain, lb.						
32 days	20.31	13.54	7.53	6.88	7.12	6.58
57 days	15.63	10.26	8.08	9.04	8.31	9.59
93 days (filled)	15.93	12.49	10.95	10.95	10.25	11.12
93 days (shrunk)	19.50	13.80	12.07	11.66	11.56	12.03

Carcass Data. Carcass data for the 24 animals slaughtered after the 93-day growing period are shown in table 3. Usually animals of this weight class would not be desirable for slaughter. However, it seemed appropriate to obtain experimental data from each feeding phase. The animals did not have sufficient finish or marbling to receive high marbling scores or carcass grades

as animals on finishing rations. Animals were graded from standard to good. No objectionable flavor was noted with any of the animals, however, and all animals received an acceptable taste panel evaluation score.

Table 3. Carcass Characteristics and Taste Panel Evaluation as Affected by Aspen Content of Diets

Item	Control	12% aspen	24% aspen	36% aspen	48% aspen	48% aspen 4% sodium hydroxide
Hot carcass wt., lb.	489.0	546.3	561.3	579.0	583.0	548.3
Dressing %	54.24	56.79	56.47	56.91	56.11	55.69
Federal carcass grade	standard	standard+	good-	good	standard+	standard+
Marbling score	2.8	3.0	3.8	3.8	3.3	3.3
Abscessed livers	1	--	--	--	--	--
Rib eye area, cm^2	69.48	79.42	76.66	73.13	77.63	76.48
Confirmation	17.8	19.0	19.3	19.5	19.0	19.3
Maturity	23.0	23.0	23.0	23.0	23.0	23.0
Color	3.5	3.8	5.3	5.0	3.8	4.8
Firmness	5.0	4.8	5.8	5.5	5.3	5.3
Kidney fat, %	1.9	1.8	2.9	2.2	1.9	2.1
Taste panel evaluation[a]						
Tenderness	3.82	3.48	3.23	4.03	3.03	2.80
Flavor	3.43	3.25	3.13	3.43	3.18	3.00
Juiciness	3.90	3.80	3.53	3.98	3.58	3.10

[a]Scored on a scale of 1 to 5 with lower values being more desirable.

Finishing Phase--Standard Rations

Feedlot performance for 24 of the animals that were continued on a finishing ration (85% corn, 15% mixed alfalfa-brome) is shown in table 4. Animals fed the control ration were lighter than animals provided all other rations at the beginning of this period because of lower gains during the growing phase. Control animals appeared to compensate by making somewhat better gains during the 85-day finishing phase but were still lighter in weight at the termination of the trial than animals on the other treatments.

Carcass characteristics and grade did not appear to be greatly influenced by previous rations (table 5).

Table 4. Feedlot Performance with Standard Finishing Diets

Item	Previous treatments					
	Control	12% aspen	24% aspen	36% aspen	48% aspen	48% aspen 4% sodium hydroxide
Number of animals	4	4	4	4	4	4
Number of days fed	85	85	85	85	85	85
Avg. initial filled wt., lb.	847.5	877.5	964.8	946.0	918.7	848.5
Avg. final filled wt., lb.	1096.5	1124.8	1159.5	1161.5	1169.0	1164.5
Avg. initial shrunk wt., lb.	791.0	837.5	927.3	912.3	873.0	909.0
Avg. final shrunk wt., lb.	1064.5	1100.0	1139.8	1128.3	1135.0	1130.5
Avg. daily gain, lb.						
33 days (filled)	4.02	3.70	1.84	2.67	2.86	3.02
61 days (filled)	3.03	3.17	2.55	2.62	3.02	2.86
85 days (filled)	2.93	2.91	2.29	2.54	2.95	2.54
85 days (shrunk)	3.22	3.09	2.50	2.54	3.08	2.61
Avg. daily ration, lb.						
33 days (consumption)	22.16	21.37	23.29	22.72	22.01	23.94
61 days	24.65	23.89	23.99	25.20	24.09	24.10
85 days	25.41	24.77	25.16	26.23	26.39	25.15
Feed/lb. gain, lb.						
33 days	5.50	5.78	12.65	8.52	7.70	7.92
61 days	8.13	7.53	9.39	9.62	7.99	8.44
85 days (filled)	8.57	8.51	10.98	10.35	8.96	9.89
85 days (shrunk)	7.86	8.08	10.14	10.39	8.62	9.72

Table 5. Carcass Characteristics and Taste Panel Evaluation with Standard Finishing Diets

Item	Previous treatments					
	Control	12% aspen	24% aspen	36% aspen	48% aspen	48% aspen 4% sodium hydroxide
Hot carcass wt., lb.	623.3	659.8	697.0	692.3	683.3	681.0
Dressing %[a]	58.59	59.97	61.14	61.41	60.20	60.24
Federal carcass grade	choice-	choice-	choice-	choice-	choice-	choice-
Marbling score	4.9	5.1	6.3	5.5	6.2	4.6
Abscessed livers	--	--	--	--	--	--
Rib eye area, cm^2	62.89	65.63	72.15	72.55	73.83	72.20
Confirmation	20.0	20.5	20.8	20.5	21.0	20.3
Maturity	23.0	23.0	23.0	23.0	23.0	23.0
Color	5.0	5.0	5.0	5.0	5.0	5.0
Firmness	5.8	4.8	5.8	5.5	5.0	5.3
Kidney fat, %	2.0	2.5	2.5	2.4	2.3	2.3
Taste panel evaluation[b]						
Tenderness	3.4	2.8	--	--	3.4	3.2
Flavor	2.5	2.4	--	--	2.6	2.6
Juiciness	3.45	3.20	--	--	3.40	3.35

[a]Determined on basis of hot carcass weight.
[b]Scored on a scale of 1 to 5 with lower values being more desirable.

Digestion and Metabolism Trial

Twelve of the animals (two from each treatment) were used in the digestion and metabolism trial. The summary of the results appears in table 6. Rations having higher apparent digestibility for the various nutrient components were also those which were associated with higher gains and feed efficiency. In general, soybean-aspen rations in this ratio were more digestible. This was indicated with all nutrients except ether extract which is a minor component in these rations.

Table 6. Digestion and Metabolism Trial on Aspen Wood Rations--Dry Matter Intake, Digestibility Coefficients and Mineral Balance

Item	Control	12% aspen	24% aspen	36% aspen	48% aspen	48% aspen 4% sodium hydroxide
Dry matter intake/100 kg body wt., kg	2.19	2.25	2.11	2.20	1.86	2.30
Apparent digestibility, %						
Dry matter	51.51	51.15	54.46	59.45	62.85	57.06
N.F.E.	59.86	63.28	59.81	67.23	68.93	61.94
Crude protein	46.71	55.13	63.64	70.73	76.64	68.63
Crude fiber	34.27	34.70	43.57	43.70	50.40	44.24
Ether extract	84.43	88.04	87.41	73.61	74.45	69.72
TDN, %	49.59	53.12	55.49	59.46	63.41	54.96
D.E., Mcal/day	14.80	18.16	18.38	22.42	20.23	21.19
Nitrogen balance						
Total intake, g/day	111.0	148.1	151.2	196.0	166.9	196.1
Retention						
Grams/day	51.4	80.2	94.8	136.5	126.4	132.4
Percent of intake	46.3	54.2	62.7	69.6	75.7	67.5
Mineral balance, g/day						
Calcium	24.10	18.02	17.48	22.62	25.38	13.20
Phosphorus	9.93	6.78	0.53	4.13	9.15	3.71

The reliability of using only two animals from each treatment for the digestion and metabolism trial could be questioned. When used in conjunction with the feedlot performance, it can be used as substantiating data to indicate trends which might be expected.

Economic Considerations

Cost of Aspen Material, Processing and Ration Preparation. A thorough cost analysis is difficult during initial phases of feasibility studies. Three cost analyses were made, however, during this first experimental trial in aspen utilization to determine the cost of harvesting and preparation of whole aspen tree material into a feed. The first cost analysis was made by the Department of Game, Fish and Parks in 1975 (table 7).

Braden Forestry Services Incorporated, Deadwood, South Dakota, was contracted to make a more extensive cost analysis of processing aspen material prior to its incorporation into animal rations. Although the entire cost analysis is too voluminous to include in this report, the essential costs per unit of production for a simulated model operation in the Black Hills are estimated in table 8.

Total Tree Incorporated, Burnsville, Minnesota, also made a cost analysis of processing aspen prior to ration preparation. This cost analysis is based on actual commercial production of aspen in volumes of 800 tons of aspen daily. Note that the analysis does not include grinding or drying of aspen, only production of wet chips loaded into 22.5 ton vans.

The cost analysis of production of wet chips in Minnesota was made on August 19, 1976, and thus should still reflect near present-day costs. If a drying and grinding charge of approximately $10 was added to wet chip production costs, prepared aspen for ration forumulation should cost on a commercial basis approximately $18.50 per ton. Both cost analyses made for the Black Hills area estimated the cost of processed aspen to be from $35 to $42 per ton.

The economic analysis of costs during experimental development of a feeding program are probably not realistic since the main objective is to determine feasibility in initial trials rather than the most economical method. This is shown by the comparison between experimental costs of harvesting aspen in the Black Hills versus the suggested commercial costs indicated by a commercial company (Total Tree Inc.).

When ration preparation from the processed aspen product is considered, the same thinking prevails. The amount of soybean meal needed to completely replace alfalfa would usually be too costly under usual price relationships between soybean meal and hay. In order for such a product to compete on the basis of cost, it would require a cheaper source of protein and energy than soybean meal. This does not defeat the objective of the feasibility study--to show whether or not it is possible to produce a product which would have similar animal utilization to alfalfa if made equal in basic nutrients. Other avenues for uses also become apparent, such as using a product which is well accepted by animals but lacks protein or other nutrients to dilute a

Table 7. Comparative Cost Data, 1975 Aspen Feeding Trial

Cost item	Cost/ton in dollars	Cost/lb. in cents	Cost per ton in dollars				
			Control	12% level	24% level	36% level	48% level
Harvesting and chipping	20.50	0.01	0	2.40	4.80	7.20	9.60
Drying	18.60	0.009	0	2.16	4.32	6.48	8.64
Grinding	1.90	0.009	0	0.22	0.44	0.66	0.88
Subtotal							
(1) Cost of aspen portion of the ration	41.00	0.0205	0	4.78	9.56	14.34	19.12
(2) Pelletizing and bagging	18.00	0.009	18.00	18.00	18.00	18.00	18.00
(3) Cost of the additive portion of ration			97.75	96.75	89.00	81.70	75.20
Total ration cost (sum of items 1-3)			115.75	119.53	116.56	114.04	112.32
Ration cost/lb.			0.58	0.060	0.058	0.057	0.056
Ration cost/lb. of gain (shrunk wt.)			1.13	0.83	0.70	0.66	0.65

Table 8. Unit Production Costs for Model Operation

Item	Dollars per ton dried chips
1. Timber purchase and acquisitions, including road building and maintenance	1.73
2. Falling and bunching of trees	9.70
3. Transportation of rough logs to central chipping and drying plant	6.93
4. Chipping process (including handling of chips to drying process)	7.36
5. Drying process (including handling of chips to storage area or loading for distribution to pelleting plant)	4.50
6. Business administration, overhead and profit margin (Profit margin computed here in 12% return on investment of capital, equipment, labor and management)	5.29
Total unit production costs	$35.51

Note: Amortization and depreciation of capital equipment are included within the cost figure for each operational phase.

traditional feed which possesses a surplus of nutrients for a certain feeding program. For example, it may be desirable to dilute corn silage for breeding animals being wintered to prevent excessive finish while saving on feed costs.

Summary and Conclusions

Aspen wood material and soybean meal in a ration of a 60:40 ratio resulted in faster rates of gain through 93 days. These ratios result in a final product comparable to good quality alfalfa. The percentage of soybean meal contributes substantially to the energy as well as the protein of the mixture. The mixture ratio appears to be equivalent in energy to the control ration as determined by the digestion trial. The results show, in general, that soybean and aspen mixtures were a satisfactory substitution for up to 80% of the alfalfa in the control ration.

Aspen steaks, from both the growing and finishing phase, were rated quite similar by the taste panel, both being acceptable with no off-flavor noted. Fat deposition in the animals which completed the finishing phase appeared somewhat abnormal. Fat was deposited in layers rather than the usual expected marbling patterns. This could have been caused by the high weight of some of the animals prior to the finishing phase.

The economic importance of utilizing aspen will depend on several factors, such as the market price of traditional feeds, the cost of harvesting and transporting aspen from its source and cheaper ways to supplement the aspen material to correct nutritional deficiencies.

Additional experiments are now in progress in which aspen serves as the roughage portion of finishing rations. An attempt is also being made to use forms of nitrogen other than soybean meal to decrease cost. Chicken manure as a source of supplemental protein is presently being investigated.