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THE POTENTIAL OF A HYDROLYZED WOOD RESIDUE AS A SOURCE OF NITROGEN, ROUGHAGE, AND ENERGY IN RUMINANT RATIONS

by

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Dedicated to the memory of my parents, Raymond B. and Edith A. Erlinger, whose encouragement and solemn entreaty provided me with the necessary motivation to continue my education.

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INTRODUCTION

At least three factors have been of primary importance in the recent increased interest in wood residues as a source of feed for livestock: (1) speculation as to large population increases by the year 2,000, (2) emphasis on the impact of pollutants on the environment, and (3) a general shortage of roughage in areas where livestock feeding has become more concentrated.

Concerning the population explosion, it is evident that the domestic meat animal will eventually compete with the human for cereal grains and other foodstuffs that are being produced for use directly by man. As a result, meat-producing animals will likely have to obtain their food supply from materials that cannot be utilized by the human. Ruminants will undoubtedly continue to play a major role in the human food chain. Because of the unique relationship with the rumen microbial population, this species can convert roughage type materials and non-protein nitrogen compounds (both of which are essentially unavailable to the monogastric) into a product that is both highly nutritious and acceptable to mankind.

Of the approximate 35 billion acres of land on the surface of the earth, 10 billion acres are forests. It is not surprising, therefore, that wood is by far the largest crop harvested annually. Associated with the wood industry are large quantities of low quality wood and non-utilized resi-

dues, which in the United States can amount to more than 100 million tons per year. Because of concern over air and water pollution, means of disposal of these materials are either lacking or prohibited. If such pollutants are biodegradable, or can be made biodegradable by processing, they offer a potential source of energy for the ruminant.

The trend toward feeding beef cattle in large, centralized operations has resulted in a shortage of conventional roughages in many of these areas. This has been particularly true in the southwest region. Thus the possibility has been raised that wood residues may find an outlet as the roughage component of prepared feeds. It has been estimated that if wood residues were used at a level of 10 percent of the ration, the quantity of such residues available annually would supply more than enough roughage for all concentrate diets fed to all livestock in the United States. It is in this area that the outlook for these residues seems most promising.

As a substitute for other feeds, wood products offer several advantages. As already mentioned, the supply is more than ample and should provide a stable market. Unlike other crops, wood products can be produced over the entire year so that the supply would be constant and the problem of storage of raw material eliminated. Also these products depend upon a crop that has grown over many years, therefore the problem of year-to-year fluctuation in production is lessened. Essentially these advantages mean that compared

to the conventional feeds, products of the wood industry could be supplied at a constant level at a relatively constant price.

Many researchers have incorporated raw sawdust directly into the diet of ruminants, and a multitude of chemical treatments (all of which are designed to increase wood digestibility) have been studied, but in spite of this a method of processing wood wastes that will consistently produce a product with desirable feeding characteristics is yet to be developed. One of the major problems in working toward this goal has been that the starting material, wood, is not a homogeneous material. This has resulted in a great deal of inconsistency between studies. Not only are there large differences in composition between the two major classes of wood, hardwoods and softwoods, but also chemical composition varies in wood taken from different parts of the same tree. For example, variation is found within a single tree from the center of the stem to the bark and from the stump to the crown. Chemical composition is likewise affected by the season of the year. As a result, the response of various woods to the same chemical treatment can be quite different. The importance of considering both the source of raw material as well as the treatment applied cannot be over emphasized when comparing the results of one study to another.

The purpose of the research reported herein was to determine if a particular acid hydrolyzed wood residue that had been neutralized with ammonia could be satisfactorily

incorporated into ruminant rations as a source of energy, roughage, or nitrogen. Since the primary goal of this investigation was to determine whether or not this product, as produced by the manufacturer, could be put into practical application, essentially no modifications were made on the hydrolyzed sawdust itself, but rather the approach taken was to modify the ration in an attempt to make optimum utilization of this ingredient. The studies included seven performance trials with cattle and lambs as well as two metabolism trials. In conjunction with the latter, the effects of hydrolyzed sawdust upon rumen pH, rumen ammonia, rumen VFA's, and blood urea were also examined.

REVIEW OF LITERATURE

Basic Wood Chemistry

Wood is a complex carbohydrate material consisting primarily of cellulose, hemicellulose, and lignin. The association of these components gives rigidity to the cell walls making them capable of withstanding the enormous stress and weight of the tree. From a nutritional aspect, however, only the cellulose and hemicellulose fractions can be utilized by the ruminant animal, and the extent of their utilization is greatly dependent upon the degree of association with lignin. Not only does the quantity of these three components vary from one species of wood to another, but also the chemical make up of the hemicellulose and lignin fractions may differ. Therefore, the feeding value of a wood, whether it be as raw sawdust or a chemically degraded product, is contingent upon its chemical composition.

The following table from Kollman and Côté (1968) is very general but gives the gross chemical composition of the two primary classes of wood. The values are expressed on an extractive-free basis. The extractives are removed by treatment with a neutral organic solvent such as alcohol, benzene, acetone or ether, although such treatment rarely renders the wood 100% extractive free. The chemical description of each component which follows the table is likewise according to the above authors.

Chemical Composition of Wood

(All values in percent of extractive-free* wood)

	Hardwood	Softwood
Cellulose	40-44	40-44
Hemicellulose	23-40	25-40
O-Acetyl-4-O-methylglucurono-Xylan	20-35	---
Glucomannans	3-5	---
Arabino-4-O-methylglucurono-Xylan	---	10-15
Galactoglucomannans	---	15-25
Lignin	18-25	25-35
Pectin	1	1
Starch	5	5
Ash	.2-.3	.2-.3

* Extractives (1-25%) include H_2O, terpenes, wood resins, polyphenols such as flavonols, quinones, and tannins, tropolones, glycosides, sugars, and fatty acids.

The primary constituent of all woods is cellulose. Cellulose is a high molecular weight polymer consisting of β-D-glucopyranose residues linked together in straight chains by (1-4) - glycosidic bonds. Cellulose is insoluble in water and aqueous alkali but is soluble in, and degraded by strong acids such as sulfuric or hydrochloric.

Hemicelluloses are low molecular weight polysaccharides soluble in water at elevated temperatures. O-Acetyl-4-O-methylglucurono-xylan, the primary hemicellulose of hardwoods, consists of a framework of (1-4) - linked β-D-Xylo-

pyranose residues with 4-O-methyl-α-D-glucuronic acid residues as side chains. Glucomannans are made up of randomly distributed β-D-glucopyranose and β-D-mannopyranose residues linked together by (1-4) - glycosidic bonds. The hemicelluloses of softwood are more complex, both with respect to the number of hemicelluloses present and with respect to their structure. Arabino-4-O-methylglucurono-Xylan consists of a backbone of (1-4) - linked β-D-Xylopyranose units with 4-O-methyl-α-D-glucuronic acid and α-L-arabinofuranose side chains. Galactoglucomannans, the predominant type of softwood hemicelluloses, have a backbone of randomly distributed (1-4) - linked β-D-glucopyranose and β-D-mannopyranose residues with a varying number of α-D-galactopyranose residues as side chains.

Lignin is a three dimensional polymer of phenylpropane units linked together by C-O-C and C-C bonds. In softwoods each unit carries one phenolic oxygen and one methoxyl group, while in hardwoods, only about half of the units contain an additional methoxyl group. Lignin cannot be hydrolyzed by acids but is soluble in strong bases and pulping agents.

The remaining components (pectin, starch, and ash) make up less than 10% of the non-extractable wood. Pectin is more abundant in bark than it is in wood. Its structure is largely unknown but contains galacturonic acid and minor quantities of arabinose and galactose. The most common

constituents of the ash component are calcium, potassium and magnesium; existing as carbonates, phosphates, silicates, and sulfates.

<u>Raw Sawdust as a Source of Roughage</u>

Prompted by an anticipated shortage of conventional roughages as well as the large quantities of wood wastes available at low costs, several researchers have recently examined the incorporation of sawdust into ruminant rations. A few reports have been encouraging. However, most studies have found the digestibility of raw sawdust to be generally poor and highly species dependent.

Millet *et al.* (1970) using the modified *in vitro* technique of Mellenberger *et al.* (1970) studied 24 species of wood and found the digestibilities of hardwoods to range from a low of 2% for red alder and sweetgum to a high of 35% for aspen. The softwoods studied were essentially indigestible (0% for hemlock, pine, and spruce to 5% for douglas-fir). Feist *et al.* (1970) using this same technique reported similar variations between species.

The effect of particle size upon the *in vitro* digestibility of wood was examined by Bender *et al.* (1970). They reported that ball milling for 24 hrs. increased the 48 hr. digestibility of aspen from 23.4% to 42.8% and from 15.1% to 50% for white birch, while having essentially no effect on three softwoods studied (fir, hemlock, and spruce). Millet *et al.* (1970) found that as milling time was increased from

zero to 240 minutes, the 48 hr. *in vitro* digestibility of red oak increased from 5% to 45% while the digestibility of aspen increased from 20% to 55%. The first 20 to 30 min. of milling appeared to have the major influence on digestibility. In agreement with the work of Bender *et al.* (1970), they reported that softwoods were much less responsive to milling than hardwoods.

There is some question as to whether finely ground wood functions as effectively in the ruminant as it does in the *in vitro* assay. Mellenberger *et al.* (1970) reported a correlation of 0.994 between the *in vitro* and *in vivo* digestibilities of complete rations containing aspen sawdust. These same authors (1971) fed goats either 0, 20, or 40% untreated aspen sawdust in both high roughage and high concentrate diets and reported that apparent digestible dry matter, digestible energy, and digestible carbohydrate decreased linearly with both types of rations as the percentage of sawdust increased. The digestibility of aspen sawdust alone was calculated by a least-squares plot of the digestion coefficients for the total ration, and then by extrapolating the resulting line to a point at which aspen would constitute 100% of the ration. By this method the authors calculated the dry matter digestibility of aspen sawdust to be 41% in a high roughage ration and 28% when incorporated into a high concentrate ration. However, in a digestibility study with lambs, Dinius *et al.* (1970) could find no difference in the dry matter digestibility of high

concentrate rations containing 0 or 10% of either aspen sawdust or oak sawdust that had been finely or coarsely ground. Since the inclusion of 10% sawdust did not significantly depress digestibility compared to the all concentrate control, these authors suggest that in high concentrate rations the sawdust itself is not digested but rather its presences results in an improved digestibility of the concentrate portion of the ration.

In other digestibility studies, Kitts *et al.* (1968) using mature wethers showed that as the level of alder sawdust increased from 0 to 35% the dry matter digestibility of a barley based ration decreased from 80.4 to 56.5% while cellulose digestibility decreased from 75.0 to 21.7%. Welton and Baumgardt (1970) found a significant decrease in ration dry matter digestibility ($P < 0.01$) but could show no effect upon digestible energy intake when the level of oak sawdust was increased from 30 to 50%. In a similar study Dinius and Baumgardt (1970) reported that sheep fed rations containing from 0 to 50% oak sawdust maintained a rather constant digestible energy intake by eating more of the oak rations up to 35% sawdust. Beyond that, total feed intake could not increase enough to maintain a constant digestible energy intake.

In a preliminary performance study Marion *et al.* (1959) found that growing steers fed a ration consisting of 34.1% ground mesquite stems plus 9.0% cottonseed hulls gained equal to a control group fed 43.1% cottonseed hulls. They

also reported that cows wintered on the mesquite stems calved normally and were in better condition than cows fed cottonseed hulls. Kinsman *et al.* (1969) fed 32 finishing lambs a 20% dried hardwood sawdust diet and reported that in general the ration produced very acceptable growth and carcass performance; there was no control ration with which comparisons could be made. Vara *et al.* (1968) fed either 14 or 28% cottonwood sawdust to young bulls in Peru. Compared to a corn cob control ration, gains were 0.1 and 0.2 Kg less, respectively for the sawdust diets, but there were no differences in carcass yield, meat quality, or in the cost of meat production.

Several studies have been conducted using oak sawdust as the sole source of roughage in finishing rations. Anthony and Cunningham (1968) reported that in both lamb and cattle finishing studies slightly improved gains were obtained by the inclusion of 2.5% oak sawdust, but increasing the sawdust level to 10% reduced gains to those obtained on the all concentrate control. In a very similar study, Anthony *et al.* (1968) compared 15% sawdust to 15% Costal bermudagrass hay. Steers fed the hay rations consumed more dry matter, had a faster rate of gain, and were more efficient than those fed 15% oak sawdust. El-Sabban *et al.* (1971) conducted two trials to determine the effect of particle size as well as level of oak sawdust in cattle finishing rations. In the first trial gains of steers fed 5 or 15% fine sawdust (band saw) and 5 or 15% coarse sawdust