The Apparent Digestibility of Lignin by Mule Deer

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During the winter of 1948 digestion studies were undertaken with mule deer to learn something of the nutritional values of browse forages that are present upon deer winter ranges of the intermountain area. When these studies were undertaken the lignin-ratio technique of digestion determination was just coming into use as a means of investigation. At the time it was decided to follow the direct method of digestion determination, since it was not certain that the lignin-ratio technique provided a proper basis for the studies planned. In consequence, however, of the adoption of the lignin-ratio technique by workers interested in the nutrition of livestock, it was later thought desirable to make additional chemical determinations to check the advisability of using the lignin-ratio technique in future deer studies. Most of the sample material from the earlier studies was still at hand, so it was possible to submit these to the laboratory for lignin and cellulose analyses. Similar determinations were also made of samples collected in subsequent digestion trials. This made possible a comparison of the direct and the lignin-ratio methods of determining digestibilities.

In theory, the lignin-ratio technique is based on the indegestibility of lignin. Considerable experimental evidence exists to show that lignin, as found in certain common livestock forages, is indeed indigestible or only slightly digestible by livestock. However, no known tests have been made to determine if similar results may be had with native, woody range plants and game animals. Because mule deer normally winter on extremely woody forages, it is conceivable that this species is able to break down fibrous plant material to a greater degree than domestic stock.

Review of Literature

Experimenters in the field of animal nutrition hold conflicting opinions about the applicability of the lignin technique. Swift, *et al.* (1947), concluded that the technique was highly valid based upon results secured from tests with sheep. This conclusion was drawn from a comparison of direct digestion trial values with lignin-ratio values in the same trials. Forbes and Garrigus (1950) reported negative lignin digestion values of from 5 to 44 percent with steers and wethers fed various grass and

legume forages. Strangely, they concluded that even a 44 percent apparent gain in lignin gave digestion coefficients by the lignin-ratio technique which departed little from the direct coefficients secured from the same trials.

Contrasting with these results Ferguson (1942) reported positive lignin digestion coefficients of from 4.4 to 16.6 percent in wheat straw fed to sheep. Bondi and Meyer (1943) recorded even more impressive positive digestion coefficients with sheep on various mediterranean forage plants, these varying from 35.1 to 64.0 percent.

Sowden and Delong (1949) studied the lignin contents of feed and feces of sheep on pasture and concluded that the lignin was broken down in the digestive tract, making the use of the lignin-ratio technique inapplicable to young plant tissues. A similar view is held by Sullivan (1955) who observed that the lignin in the feces was more vulnerable to attack by strong acids and weak alkalis than was the lignin in the feed of the grasses being tested.

Cook, *et al.* (1954), used the lignin-ratio technique on woody range plants, apparently without testing the digestibility of lignin in the plants studied.

Method and Procedure

The data reported in this study were obtained from digestion trials conducted with mule deer (*Odocoileus hemionus*) during the winters of 1947-48, 1948-49, 1950-51, 1952-53, and 1953-54. Trials with two sheep were made on alfalfa hay in 1948-49. The tests were made near Logan, Utah.

Plants fed during the trials were all native shrubby species except alfalfa hay. The species tested were curlleaf mahogany (*Cercocarpus ledifolius*), birchleaf mahogany (*Cercocarpus montanus*), cliffrose (*Cowania stansburiana*), chokecherry (*Prunus virginiana*), Gambel oak (*Quercus gambelii*), Utah juniper (*Juniperus utahensis*), bitterbush (*Purshia tridentata*), sagebrush (*Artemisia tridentata* ssp. *typica*) and cured alfalfa hay.

Table 1. Percent lignin in six forage and feces samples, showing eight separate determinations for each sample.

Sample	Number and date of analysis 1 May '53	2 Aug. '53	3 Jan. '54	4 Jan. '54	5 Jan. '54	6 Jan. '54	7 Feb. '54	8 Feb. '54	Mean	Range
			Cliffrose		Deer no. 53-11					
Feed	16.3	18.9	17.7	17.4	14.4	14.9	13 8	13.1	15.8	13.1—18.9
Orts	14.5	22.9	25 0	24.8	22.1	22.3	22.1	21.4	21.9	14.5—25.0
Feces	31.9	31.3	33.4	33.6	32.4	32.1	31.4	33.0	32.4	31.3—33.6
			Chokecherry		Deer no. 53-10					
Feed	27.7	27.5	28.4	28.1	25.5	26.5	24.8	24.5	26.6	24.5—28.4
Orts	25.9	26.2	27.2	27.4	24.7	24.7	23.0	23.7	25.4	23.0—27.4
Feces	35.6	33.7	33.9	35.2	32.5	33.9	32.9	33.3	33.9	32.5—35.6

The deer used in the tests varied in age from less than a year to mature animals. All of the trials included one animal less than a year old, except in tests of cliffrose and Gambel oak, in which two fawns were used. Five deer were tested with curlleaf mahogany, cliffrose, Gambel oak, and Utah juniper. Four were fed birchleaf mahogany, chokecherry, bitterbrush, and alfalfa hay. Although six deer originally were tested upon sagebrush, sample material had been discarded from all but two animals fed this species.

Metabolism cages, described in an earlier publication, were used (Smith 1950). All deer were given the feed to be studied for a preliminary period of several days prior to being placed in the metabolism cages. After the deer were in the cages, the preliminary feeding was continued from two to five days before the collection period began. The duration of preliminary feeding in the cages depends on the length of feeding previous to being placed in cages. The collection period was at least seven days, most being 10 days.

Feed, orts (rejected feed) and fecal samples were submitted to the Utah State Agricultural College animal nutrition laboratory for chemical analysis. The same chemist made all determinations reported in this paper. Lignin determinations were made as suggested by Ellis, *et al.* (1946) as modified by Forbes and Hamilton (1952). In some of the re-analysis later described, a further modification in the following process was adopted from Stamm and Harris (1953).[1]

Results and Discussion

Chemical analysis — A perusal of the initial lignin values revealed irregularities in the chemical determinations. Because the sensitivity of the quantitative lignin analysis is basic to the appropriateness of the lignin-ratio technique, it was decided to pursue this question further. Accordingly, material from two digestion trials, containing samples of feed, orts and feces from a deer fed cliffrose and a deer fed chokecherry, were selected for resubmission to the chemist (Table 1). Eight lignin analysis figures were secured for each of the six samples.

The first analysis was made in May, 1953, the second in August, 1953; and the third, fourth, fifth, and sixth in January, 1953; and the seventh and eighth in February, 1954.

The third and fourth analyses were laboratory duplicate values run by the chemist on the same day. The fifth and sixth analyses were laboratory duplicate samples tested a day later. The seventh and eighth analyses were laboratory duplicate samples tested approximately a month later. Except for these duplicate determinations, the identical status of materials tested was unknown to the chemist.

The variation in lignin values for the same sample is considerable

[1]*The authors acknowledge the aid of David O. Williamson for chemical analysis of material.*

Table 2. Apparent digestibility of lignin in nine forage species by deer and alfalfa hay by sheep.

Forage	Digestion Trial						
	1	2	3	4	5	Mean	Range
				—%—			
Birchleaf mahogany	31.0	23.8	30.8	42.1	——	31.9	23.8-42.1
Bitterbrush	30.0	18.8	22.2	23.0	——	23.5	18.8-30.0
Chokecherry	20.6	36.2	35.8	17.0	——	27.7	17.0-36.2
Cliffrose	-7.2	-2.7	-0.1	32.8	13.0	7.2	-7.2-32.8
Curlleaf mahogany	26.0	15.8	19.9	21.7	11.0	18.9	11.2-26.0
Gambel oak	26.7	21.9	24.4	30.2	15.5	23.7	15.5-30.2
Sagebrush	33.9	30.1	——	——	——	32.0	30.1-33.9
Utah juniper	16.9	9.3	27.6	25.1	——	19.7	9.3-27.6
Alfalfa hay—deer	1.8	7.5	3.9	11.1	——	5.8	1.8-11.1
Alfalfa hay—sheep	9.2	14.9	——	——	——	12.1	9.2-14.9

(Table 1). In the case of the orts of cliffrose, the maximum value reported is 172 percent that of the lowest. Obviously, greatly different digestion coefficients are possible depending upon which of the sets of values might have been received from the laboratory. These data suggest that the determination of lignin in material high in lignin is not a satisfactorily developed technique, a conclusion given weight by parallel conclusions of wood chemists (Stamm and Harris, 1953). Moreover, other investigators have similarly questioned the accuracy of lignin determinations made upon herbaceous material (Sowden and DeLong, 1949).

Digestibilities of lignin—Although the problem of chemical separation of lignin seemed not adequately solved, there appeared to be justification for proceding with calculations of lignin digestibility, since the methods used were those which had been employed by other investigators.

In all cases, the average of the several determinations is positive, varying between 5.8 and 32.0. However, in the case of cliffrose, the average is open to question since all three determinations made during 1953 were negative (the only instances in which negative values appeared) while the two tests made in 1954 were positive. These data suggest the possibility of some procedural error having been made, perhaps in the method of securing samples. In view of the positive values secured in all other intances, the 1953 values for cliffrose are perhaps questionable.

The comparatively low digestion values secured with a dry forage (alfalfa hay) may be of significance in view of the results reported by Miller *et al.* (1954.) Although the test animals were rabbits, they report marked differences in the digestibility of lignin from green as compared to dried feed from the same species. The differences were 4.7, 3.2, and 6.8 percent greater digestibility of lignin for green material of ladino clover, tall fescue and orchard grass respectively than for dry material of the same species.

It is interesting to note that in the two trials with sheep on alfalfa hay (Table 2), the sheep were apparently able to digest a greater percentage of alfalfa hay lignin (ave. 12.1) than were deer (5.8). While two trials are not sufficient to conclude that sheep do digest lignin, these results, in the light of the deer data, raise a serious question in the case of sheep too.

Comparison of values determined by lignin ratio method with direct measurement—Table 3 shows the digestion values for certain constituents which would have been secured had the method of study relied upon the lignin-ratio method, together with values secured from direct measurement. In all cases, the lignin-ratio method gave lower values than were found by measurement. Apparently, there is no basis for using the lignin-ratio approach in studying winter diets of mule deer until such time as a more reliable method for lignin analysis is available.

Little basis exists for comparing the digestive abilities of deer and sheep on the same forages. The only known instances wherein one of the plants in this experiment was tested by others is that of big sagebrush by Cook, *et al.* (1954). From our own data comparative tests are available on alfalfa hay with both deer and sheep. The comparative findings are given in Table 4. Although these data are meager there appears to be no basis for assuming that deer and sheep behave dissimilarly with respect to digestion of fibrous mate-

Table 3. Comparison of measured digestibility values with those obtained by lignin-ratio calculation.

Forage	Feed Intake		Apparent Digestibilities					
			Protein		Ether Extract		Cellulose	
	By direct determination	By lignin-ratio	By direct determination	By lignin-ratio	By direct determination	By lignin-ratio	By direct determination	By lignin-ratio
	(*grams, oven dry*)		%		%		%	
Birchleaf mahogany	808	534	48.5	24.2	37.6	7.5	43.4	17.1
Bitterbrush	793	604	35.7	15.4	53.0	37.9	19.6	-5.2
Chokecherry	685	488	48.4	28.9	23.3	-7.7	21.2	-23.8
Cliffrose	1,113	1,018	39.8	33.3	47.7	42.7	16.6	1.9
Curlleaf mahogany	667	534	54.3	43.1	42.9	29.1	41.2	27.4
Gambel oak	1,076	817	10.7	-17.9	33.8	13.2	23.7	9.5
Sagebrush	581	485	68.7	54.0	70.9	49.1	65.5	49.6
Utah juniper	538	425	16.8	-3.4	58.9	48.9	39.3	24.4
Alfalfa hay—deer	890	839	76.9	75.4	16.9	9.2	59.3	56.4

rial. In only one instance do the coefficients calculated for deer and sheep show pronounced differences, that of ether extract from sagebrush.

The study does not provide a clear-cut answer as to the actual digestibility of lignin. In view of the fact that the lignin determination is especially difficult with woody materials, it is possible that the apparent digestibility is explainable by the inability of the chemists to separate lignin from other fractions of the feed. However, from the practical standpoint, this is unimportant. The fact that chemists skilled in the determination cannot determine lignin content accurately invalidates the lignin-ratio technique as a basis for computing the digestibilities of native forages high in woody materials.

Summary

Digestion coefficients were calculated for browse species native to Utah in addition to alfalfa hay when fed to mule deer. Calculations were made by both the direct method and by the lignin-ratio technique.

Digestion coefficients for lignin were positive except for three trials made with cliffrose. Positive mean values varied from 9.3 to 42.1 digestibility for the native species. Smaller values were secured in the case of alfalfa hay.

Difficulty was encountered in making consistent lignin determinations in the laboratory. Considerable variation in results was secured from repeated analysis of the test materials.

Markedly different digestion values resulted from the lignin-ratio technique as compared to conventional analysis in the case of the native forages. On the basis of limited data it seems possible that these differences were not attributable to the species of animal used, for marked agreement existed in limited data from deer and sheep on the same materials.

No clear inference may be drawn as to whether the apparent digestion of lignin is due to inability to isolate the material or to actual digestion. In either event the lignin-ratio technique appears to be of doubtful validity on the type of forages used.

Table 4: Comparative digestion values for deer and sheep on sagebrush and alfalfa.

Plant	Animal	Method	Protein	Ether Extract	Cellulose
Sagebrush	sheep*	Lignin ratio	54.7	74.6	33.7
	deer	Lignin ratio	54.0	49.1	49.6
	deer	Direct	68.7	70.9	65.5
Alfalfa Hay	deer	Lignin ratio	75.7	10.6	56.4
	deer	Direct	76.9	16.9	59.3
Alfalfa Hay	sheep	Lignin ratio	71.1	37.5	45.0
	sheep	Direct	74.6	45.5	51.8

*Cook *et al.* (1954)

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