# COMPOSITION AND DIGESTIBLE ENERGY OF HAYS FED TO CATTLE[1]

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## INTRODUCTION

The evaluation of feeds is the subject of a report by a committee of the American Society of Animal Production written by Mitchell (*10*).[2] This reviewed the relations that have been found to exist between constituents determined chemically and certain items in the utilization of feeds. The close negative relation between crude fiber content and the digestibility of the organic matter of feeds by different species of animals was emphasized especially. The committee suggested that further studies along these lines might yield valuable results.

Dissatisfaction with the standard methods of analysis has been expressed frequently. Crampton and Forshaw (*4*) among others, have attempted to use more detailed determinations, especially of the carbohydrate fractions, in studies of the relation of composition to the usefulness of feeds. The results have been disappointing. So far no carbohydrates or grouping of carbohydrates known or supposed to be utilizable have been found which are clearly related to the energy animals can obtain from feeds.

In the present limited study it was hoped that some definite relations between composition and useful energy might be found if the number of variables were reduced as far as possible. For this purpose investigators known to have conducted experiments on the energy metabolism of farm animals were asked if they could supply samples of essentially pure stands of grasses or hays that had been used as the sole ration in energy utilization studies with cattle. To supplement the data supplied by the cooperating investigators, these samples were to be analyzed in this laboratory as completely as practicable, with especial attention to the carbohydrate fractions. The items of composition were then to be compared with the results of the digestion experiments.

## MATERIAL AND METHODS

The conditions proposed above limited the number of samples that could be found. Eventually 25 were received, as follows: 10 of

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[2] Italic numbers in parentheses refer to Literature Cited, p. 395.

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timothy, of which No. 9 was grass fed fresh; 1 of bromegrass; 1 of oat hay; 1 of Sudan grass; 1 of mixed grass, largely redtop, fed fresh (No. 8); 7 of alfalfa; 1 of red clover; 1 of alsike; 1 of soybean hay; 1 of lespedeza. With the 2 exceptions noted, all were fed as hay.[3]

Accompanying each sample were the results that had been obtained for digestible energy and the digestibility of the dry matter. In many cases the metabolizable energy had been determined either directly or by calculation. The results of the standard feedingstuff analyses also were provided with many of the samples.

The samples were analyzed in the writers' laboratory by the methods used in a previous study of timothy (*11*) except that the extraction was modified for dry samples. These were extracted in a Soxhlet apparatus, first with anhydrous ethyl ether, then with 95 percent ethyl alcohol. The material extracted by alcohol did not all remain in solution but dissolved when enough water was added to make the alcohol concentration 80 percent.

The items or groups used in the comparisons were (1) protein, (2) lignin, (3) cellulose, (4) hemicellulose, (5) total carbohydrate as suggested by Crampton and Whiting (*6*) including hemicellulose, starch if present, fructosans if present, and the sugars, all calculated to the starch equivalent, and (6) crude fiber.

These categories of materials were compared with (1) the digestibility of the energy, (2) the digestible energy in calories per gram, and (3) the digestibility of the dry matter. Since the heats of combustion of the samples differed only slightly the relations of constituents to (1) and (2) are so nearly identical that only the former are presented. The relations to (1) and (3) also are quite similar. These relationships were graphed and the corresponding correlation coefficients and regression equations were calculated.

## RESULTS OF ANALYSES

It was found that metabolizable energy had not been determined for 7 of the samples and that the data for calculating it were not available. Therefore this item could not be used in the comparisons. The relation between metabolizable energy and digestible energy for the remaining 18 samples was plotted and the correlation coefficient was calculated. The graph was a straight line one with $r=+0.948$. In this limited group of samples, then, the relation between these items is very close.

The data used in the rest of the calculations are presented in table 1. The figures for digestibility and many of those for crude fiber were supplied by the cooperating investigators. The remainder of the items were determined in this laboratory.

[3] The cooperation of the following, who supplied one or more of the samples and the relevant data, is gratefully acknowledged: J. A. Newlander, University of Vermont; Max Kleiber, University of California; H. H. Mitchell, University of Illinois; H. A. Herman, University of Missouri; E. G. Ritzman, University of New Hampshire; R. W. Swift, Pennsylvania State College.

TABLE 1.—*Digestibility and composition of hays*

| Sample No. | Species | Digestible energy | Digestibility of— | | Composition (percent of dry weight) of— | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Energy | Dry matter | Protein | Hemicellulose | Total carbohydrates | Cellulose | Lignin | Crude fiber |
| | | *Cal. per gm.* | *Percent* | *Percent* | | | | | | |
| 7 | Timothy | 2,567 | 57.7 | 60.4 | 5.98 | 14.83 | 28.95 | 30.14 | 9.85 | 33.0 |
| 9 | do | 3,534 | 78.6 | 80.8 | 11.36 | 13.28 | 25.51 | 24.94 | 6.92 | 24.0 |
| 12 | do | 2,493 | 55.7 | 56.7 | 5.41 | 17.10 | 27.28 | 33.72 | 10.56 | 34.8 |
| 15 | do | 2,498 | 56.4 | 59.3 | 8.31 | 15.03 | 19.91 | 32.62 | 10.51 | 33.5 |
| 16 | do | 2,856 | 62.4 | 64.4 | 8.00 | 17.61 | 22.01 | 37.20 | 9.60 | 34.7 |
| 17 | do | 2,387 | 53.2 | 54.8 | 5.89 | 15.57 | 25.98 | 34.53 | 11.49 | 34.1 |
| 19 | do | 2,232 | 49.6 | 47.3 | 7.27 | 16.34 | 22.81 | 34.20 | 11.53 | 34.9 |
| 22 | do | 2,785 | 62.0 | 65.3 | 9.07 | 17.20 | 23.39 | 30.54 | 9.69 | 33.1 |
| 24 | do | 2,569 | 59.6 | 61.7 | 9.44 | 13.51 | 23.82 | 28.13 | 9.82 | 30.0 |
| 25 | do | 2,828 | 64.6 | 67.2 | 8.78 | 16.07 | 23.77 | 27.12 | 8.16 | 29.0 |
| 1 | Bromegrass | 2,949 | 67.6 | 69.4 | 12.15 | 15.97 | 20.85 | 30.98 | 7.58 | 31.1 |
| 6 | Oat hay | 3,033 | 66.8 | 67.5 | 13.75 | 15.61 | 18.95 | 30.52 | 8.54 | 30.0 |
| 8 | Mixed | 2,332 | 51.7 | 62.5 | 7.28 | 14.89 | 25.54 | 31.29 | 9.45 | 32.8 |
| 23 | Sudan | 2,861 | 67.8 | -------- | 12.59 | 13.62 | 22.22 | 27.90 | 8.24 | 27.2 |
| 2 | Alfalfa | 2,670 | 59.7 | 60.4 | 16.73 | 8.84 | 13.90 | 27.09 | 11.14 | 33.4 |
| 3 | do | 3,032 | 67.0 | 67.6 | 22.00 | 8.26 | 13.52 | 23.51 | 8.97 | 26.1 |
| 10 | do | 2,809 | 61.2 | 62.2 | 18.47 | 9.60 | 11.80 | 25.50 | 10.74 | 30.9 |
| 11 | do | 2,463 | 54.5 | 56.2 | 14.43 | 9.76 | 12.35 | 32.60 | 11.92 | 32.8 |
| 14 | do | 2,508 | 56.7 | 59.0 | 16.26 | 10.63 | 12.48 | 28.66 | 11.12 | 32.8 |
| 18 | do | 2,659 | 58.1 | 59.2 | 17.84 | 9.34 | 11.65 | 26.88 | 11.01 | 30.6 |
| 21 | do | 2,466 | 54.7 | 56.6 | 13.78 | 9.52 | 13.08 | 34.00 | 12.91 | 40.5 |
| 4 | Red clover | 2,599 | 60.1 | 59.9 | 12.50 | 8.75 | 16.01 | 28.77 | 11.00 | 30.4 |
| 5 | Alsike | 2,522 | 57.0 | 58.8 | 11.24 | 12.58 | 15.80 | 31.61 | 11.43 | 30.2 |
| 20 | Soybean hay | 2,889 | 63.7 | 60.7 | 11.24 | 13.15 | 19.54 | 35.20 | 11.38 | 33.1 |
| 26 | Lespedeza | 2,596 | 57.5 | 58.0 | 12.15 | 9.29 | 16.01 | 27.19 | 13.19 | 32.2 |

The relation between the protein content of the samples of timothy and alfalfa and the digestibility of their energy is shown in figure 1.

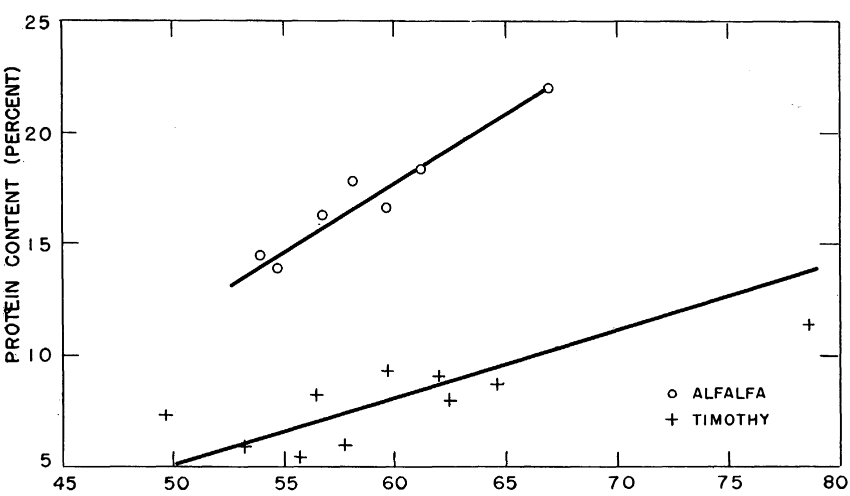


FIGURE 1.—Relation between protein content of the samples of timothy and alfalfa and the digestibility of their energy. For alfalfa $r=+0.966$, for timothy $r=+0.786$, for both $r=+0.244$.

In each of the species this relation is highly significant, but at different levels of protein content. When all 17 samples are considered the relation is not significant. Similar specific differences were evident to a greater or less extent in all the relations studied.

It was considered advisable then to study the 10 timothy samples and the 7 alfalfa samples separately and to ignore the other species. This reduced the number of samples in each comparison greatly and so decreased the value of the results.

Such relations among the major items considered as were found to be significant are listed in table 2. No significant relations were found between digestibility and content of hemicellulose or of total carbohydrates.

For the timothy and alfalfa samples, separately, the regression equations for calculating the digestibility of the energy and the digestibility of the dry matter, respectively, from the content of lignin, of crude fiber, and of protein are presented in table 3. Also included are the direct correlation coefficients, the standard deviations of the two digestibilities, and the standard error of estimate of each of these when calculated from the constituent indicated.

The large "a" values in some of these equations show the danger of extrapolating beyond the range of the data at hand. They indicate either that the relations would not follow a straight line at extreme values of the variables, or that a wider range of data would result in an appreciable change in the slope of the regression line.

TABLE 2.—*Correlation coefficients*

| Variables | Percent lignin | Percent crude fiber | Percent protein | Percent cellulose |
|---|---|---|---|---|
| Timothy: | | | | |
| Digestibility of energy | −0.962 | −0.872 | +0.786 | −0.689* |
| Digestibility of dry matter | −.954 | −.842 | +.761* | −.689* |
| Alfalfa: | | | | |
| Digestibility of energy | −.932 | −.787* | +.966 | −.899 |
| Digestibility of dry matter | −.939 | −.784* | +.966 | −.889 |

*Significant at the 5-percent level; all others at the 1-percent level.

TABLE 3.—*Regression equations, digestibility of constituents*

| $y$ | $x$ | $r$-$xy$ | Equation | $Sy$ | $Sy.x$ |
|---|---|---|---|---|---|
| TIMOTHY | | | | | |
| | *Percent* | | | | |
| Digestibility of energy | Lignin | −0.962 | $y=113.1-5.41x$ | 7.94 | 2.29 |
| | Crude fiber | −.872 | $y=123.8-2.00x$ | 7.94 | 4.13 |
| | Protein | +.786 | $y=33.2+3.37x$ | 7.94 | 5.21 |
| Digestibility of dry matter | Lignin | −.954 | $y=120.3-5.96x$ | 8.84 | 2.83 |
| | Crude fiber | −.842 | $y=130.3-2.14x$ | 8.84 | 5.06 |
| | Protein | +.761 | $y=33.0+3.62x$ | 8.84 | 6.08 |
| ALFALFA | | | | | |
| Digestibility of energy | Lignin | −0.932 | $y=96.5-3.39x$ | 4.36 | 1.73 |
| | Crude fiber | −.787 | $y=84.6-0.79x$ | 4.36 | 2.95 |
| | Protein | +.966 | $y=32.7+1.53x$ | 4.36 | 1.24 |
| Digestibility of dry matter | Lignin | −.939 | $y=93.9-3.04x$ | 3.88 | 1.46 |
| | Crude fiber | −.784 | $y=83.0-0.70x$ | 3.88 | 2.64 |
| | Protein | +.966 | $y=36.9+1.36x$ | 3.88 | 1.10 |

## DISCUSSION

Crampton and Forshaw (*4*) compared the gains in weight of rabbits with the composition of the grass clippings used as feed. Lignin was negatively correlated with gains, but the result did not reach even the 5-percent level of significance. The very high correlation of −0.978 was found by Lancaster (*8*) between the lignin content of 14 feeds and the digestibility of their organic matter by sheep. The feeds included both succulents and hays. Lancaster concluded that the superiority of lignin as a factor in feed evaluation is not clearly established. The determination is not yet satisfactory and further studies are needed.

The results of the present study give further evidence of the importance of this relation. Lignin content is closely related to digestibility of energy in both timothy and alfalfa, and thus in the limited sampling available, it is shown to be an excellent basis for calculating digestibility in each of the species. It should be noted, however, that the regression coefficients, which measure the change in digestibility corresponding to an increase of 1 percent in lignin content, are strikingly different for the two species,—5.41 for timothy and—3.39 for alfalfa (table 3).

Reports on the relation of crude fiber to the digestibility of the organic matter of feeds are more numerous. Some recent results are summarized in table 4. McMeekan's figures include a wide variety

TABLE 4.—*Relation between digestibility of organic matter and crude fiber conten*

| Source of data | Number of items | Correlation coefficient | Regression coefficient |
|---|---|---|---|
| Cattle: | | | |
| Axelsson (*1*) | | | −0.879 |
| Brouwer and Dijkstra (*3*) | 9 | −0.784 | −1.134 |
| Brouwer and Dijkstra (*3*)[1] | 10 | −.557 | −.515 |
| Duckworth (*7*) American cattle [1] | 101 | −.680 | −.918 |
| Duckworth (*7*) Zebu cattle [1] | 166 | −.417 | −.511 |
| Sheep: | | | |
| Brouwer and Dijkstra (*3*)[1] | 38 | −.674 | −.992 |
| Brouwer and Dijkstra (*3*)[1] | 22 | −.525 | −.720 |
| Brouwer and Dijkstra (*3*)[1] | 15 | −.599 | −.479 |
| Brouwer and Dijkstra (*3*)[1] | 48 | −.518 | −.564 |
| Lancaster (*8*) | 14 | −.944 | [2] −1.698 |
| McMeekan (*9*)[1] | 50 | −.944 | −.960 |

[1] Calculated from the results of digestion experiments assembled from the literature.
[2] Calculated from Lancaster's data.

of feeds, succulents, silages, roughages, and concentrates. Lancaster's include succulents and roughages. The rest are largely limited to grasses and hays. Duckworth included only roughages exclusive of silages.

All the correlation coefficients listed in table 4 show definite trends, but only the highest ones indicate a relationship close enough to permit the constituent to be used as a reasonably satisfactory measure of digestibility.

The regression coefficients also vary widely. Axelsson (*2*) has explained some of the variations in this figure on the basis of differences in experimental technique and has emphasized the need for the standardization of methods in digestibility trials.

The results reported here for crude fiber (tables 2 and 3) are well within the range of those assembled from the literature (table 4). In the samplings of both timothy and alfalfa the relation between crude fiber content and digestibility of energy is significant, though not as close as the lignin relationship. Here, again, the differences in the regression coefficients relating differences in crude fiber content to differences in digestibility are striking, −2.00 for timothy and −0.79 for alfalfa.

The regression coefficients found by other workers (table 4) also vary widely, from −0.479 to −1.698. It is quite impossible to select from these varying values one which could be used with confidence in calculating the digestible energy of feeds from their crude fiber content.

In the alfalfa samples the protein content is very closely related to the digestibility of energy, but in the timothy samples this relation barely reaches the 1-percent level of significance.

The cellulose relationships differ in the same way as those of protein but are at an appreciably lower level of significance.

For neither timothy nor alfalfa do any of the groupings of carbohydrates studied show a significant relation to the energy yield. These results confirm at least the latter part of a statement made by Crampton and Jackson (*5, p. 339*), "Protein and fiber fail as indices of nutritive value as do all other fractions reported in this paper."

The relations found in this study are limited in value because of the small number of samples included. Those with lignin, however, are extremely close, and different for the two species. It is likely that they would be much less marked in studies of mixed herbage whose botanical composition varied widely.

## SUMMARY

Twenty-five samples of hays received from various laboratories in the United States were studied. These hays had served as the sole ration in feeding experiments with cattle. Each sample was from an essentially pure stand of a single species of grass or legume.

The samples were analyzed chemically and their composition was compared with the results of the feeding trials.

Comparison of the digestible and the metabolizable energy of the 18 samples for which the latter value had been determined show a very close relation between the two.

Species differences were so pronounced that it was considered advisable to make separate studies of the 10 samples of timothy and the 7 of alfalfa. The other samples, one each of 8 species, were not included. Thus the number of samples used in the comparisons was small.

The lignin, protein, cellulose, and crude fiber content of the samples all are related more or less closely to their yield of energy but at differing levels of these constituents for the two species.

When applied to the samples of each of the two species separately, the lignin content serves as an excellent means of estimating the digestibility of energy and of dry matter.

Crude fiber content also is related significantly to the digestibility of energy, but less closely than the lignin content.

The regression coefficients relating differences in a constituent to differences in digestibility differ widely for the two species.

The carbohydrate fractions studied, other than cellulose, show no significant relation to the digestibility of either energy or dry matter.

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