UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
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DIGESTION EXPERIMENTS WITH RANGE FORAGES AND FLAX HULLS

H. R. GUILBERT and H. GOSS

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CONTENTS

	PAGE
Introduction	3
Digestion trials with range forage	3
Digestion trials with flax hulls	6
Discussion	8
Acknowledgment	10

DIGESTION EXPERIMENTS WITH RANGE FORAGES AND FLAX HULLS[1]

H. R. GUILBERT[2] and H. GOSS[3]

INTRODUCTION

THIS REPORT is a continuation of a series on the nutritive value of various feeds. As before, the purpose is to assist livestock men in utilizing feed resources more efficiently.

This paper contains the results of digestion trials with broad-leaf filaree, range grasses, Spanish clover, and flax hulls. Wether sheep were used as experimental animals, and the methods were similar to those employed previously and described in Bulletin 409.[4]

DIGESTION TRIALS WITH RANGE FORAGES

Digestion trials have already been reported on dry mature filaree, bur clover, and mixed annual grasses.[5] In these experiments each feed was given as the sole ration. Mature filaree and annual grasses are deficient in protein. Since supplemental feeding of protein concentrates improves the welfare of grazing animals and the utilization of such range forage, it appeared desirable to repeat the trials on these two feeds, using a protein supplement. Spanish clover, a late-growing legume, remains green and therefore may attract the cattle after most other forage has matured and dried. No data on its digestibility were available. Besides the usual analyses, information was desired on the digestibility of lignin, cellulose, and "other carbohydrate" portions of the carbohydrate fraction of the feeds reported in this paper.

The filaree (*Erodium Botrys*), the mixed annual grasses—consisting mostly of soft chess (*Bromus mollis*), fescue (*Festuca* spp.), and slender wild oats (*Avena barbata*)—and the Spanish clover (*Lotus americanus*) were all collected by K. A. Wagnon on the San Joaquin Experimental Range in the summers of 1940 and 1941. To facilitate uniform mixing, the forage was coarsely ground in a hammer mill fitted with a ⅜-inch screen.

Since the sheep had been on good feed, they were somewhat reluctant to consume sufficient quantities of these relatively unpalatable feeds.

Casein was used as a protein supplement because it has high purity and digestibility and will therefore not complicate the calculation of the digestibility of the feeds in question. Some of the animals, however, refused to eat the dry, ground casein. To overcome this difficulty in the trials with filaree and grass, equal parts of casein and forage were moistened with water and thor-

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[1] Received for publication July 28, 1943.

[2] Associate Professor of Animal Husbandry and Associate Animal Husbandman in the Experiment Station.

[3] Associate Professor of Animal Husbandry and Associate Animal Husbandman in the Experiment Station.

[4] Mead, S. W., and H. R. Guilbert. The digestibility of certain fruit by-products as determined for ruminants. Part I: Dried orange pulp and raisin pulp. California Agr. Exp. Sta. Bul. 409:1–12. 1926. (Out of print.)

[5] Hart, G. H., H. R. Guilbert, and H. Goss. Seasonal changes in the chemical composition of range forage and their relation to the nutrition of animals. California Agr. Exp. Sta. Bul. 543:1–62. 1932. (Out of print.)

oughly mixed. The mixture was then dried in an oven at 80° C. The resultant cake, broken up, was added to the remainder of each sheep's ration in amounts to furnish the desired casein. The casein adhered to the forage, and the animals ate it well in this form.

In these trials each sheep received 80 grams of casein daily, while the range forage varied from 320 to 600 grams daily.

Even greater difficulty was encountered with the Spanish clover, which was harvested green at an advanced stage of growth comparable with that at which it is usually eaten on the range. Having a rather pungent odor and bitter flavor, it was disliked by the sheep. A ration of 80 per cent Spanish clover and 20 per cent casein was moistened, thoroughly mixed, and dried. It

TABLE 1

PERCENTAGE COMPOSITION OF MATURE DRY ANNUAL GRASSES AND FILAREE, AND OF SPANISH CLOVER HARVESTED GREEN AND THEN DRIED

(Determinations calculated on dry basis)

Feed	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Lignin	Cellulose	Other carbohydrates
Annual range grasses	4.05	46.05	1.40	40.09	8.47	16.52	39.95	29.67
Filaree	3.98	49.50	1.73	35.27	9.52	13.03	41.78	29.94
Spanish clover	11.80	55.91	1.86	24.15	6.28	25.43	25.97	28.66

was placed in a single pile, again mixed, and sampled; and individual feeds for each sheep were weighed out into paper bags. Two of the three sheep used consumed 500 grams daily of this mixture; and the third, 400 grams.

For at least 5 days before the trials began, the animals were fed daily the same quantity that they received during the feces-collection period. Collections in each case continued for 10 days.

Table 1 shows the chemical composition of the dry matter of the three forages. Lignin and cellulose determinations were made by the method of Crampton and Maynard.[6] "Other carbohydrates" are undetermined nitrogen-free material, largely sugars and starch obtained by subtracting the sum of the protein, ether extract, ash, lignin, and cellulose from 100. Table 2 gives the coefficients of apparent digestibility.

In the trial with annual range grass, sheep 4 digested less of the forage than either of his mates. With this exception, the results with the different animals agreed reasonably well.

The dry matter of filaree was more digestible than that of either the annual grasses or the Spanish clover. Filaree has the lowest lignin content. Lignin not only is very low in digestibility, but by forming encrusting material on the cell walls appears to decrease the digestibility of other nutrients, presumably by protecting them more or less from the action of digestive enzymes.

As table 2 shows, the crude fiber of the grass was more highly digestible than the nitrogen-free extract, whereas the reverse was true in the filaree and the Spanish clover. This confirms other experiments showing the limitation of crude-fiber determination as an index of feed value when applied to roughages.

[6] Crampton, E. W., and L. A. Maynard. The relation of cellulose and lignin content to the nutritive value of animal feeds. Jour. Nutr. 10:383–95. 1938.

The nitrogen-free extract does not always represent the more digestible starches and sugars; conversely, crude fiber may not represent the material of lower digestibility. Partitioning the carbohydrate into lignin, cellulose, and "other carbohydrates" does divide the feed into fractions of consistently different availabilities; it is therefore more useful in predicting feed value from chemical analyses.

TABLE 2

COEFFICIENTS OF APPARENT DIGESTIBILITY OF MATURE DRY ANNUAL GRASSES AND FILAREE, AND OF SPANISH CLOVER HARVESTED GREEN AND THEN DRIED

Sheep no.	Dry matter	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber	Lignin	Cellulose	Other carbohydrates
				Annual range grasses				
6	46.8	−15.8	49.4	46.8	56.0	23.5	57.5	62.1
4	33.5	−39.5	34.1	33.4	45.3	− 1.5	47.4	51.2
8	48.6	−18.2	52.1	37.6	62.7	19.1	63.6	69.3
Average	*43.0*	*−24.5*	*45.2*	*39.3*	*54.7*	*13.7*	*56.2*	*60.9*
				Filaree				
7	51.0	−24.5	62.4	54.2	45.2	11.0	61.6	65.7
1	49.2	−38.3	60.6	54.4	44.2	11.9	60.1	63.1
2	48.6	−46.8	60.5	51.7	44.8	6.1	61.3	64.3
Average	*49.6*	*−36.6*	*61.1*	*53.5*	*44.8*	*9.7*	*61.0*	*64.4*
				Spanish clover				
1	43.4	19.4	56.9	37.5	32.9	− 9.9	53.1	99.2
2	45.6	22.5	58.1	40.2	38.1	− 8.9	56.3	100.0
3	40.2	14.5	54.4	34.1	30.6	−20.0	49.4	100.0
Average	*43.0*	*18.8*	*56.5*	*37.3*	*33.9*	*−12.9*	*52.9*	*99.7*

In the trial with Spanish clover, the analyses showed more lignin recovered in the feces than was present in the feed; the result is a minus coefficient. The cause may have been the mechanical difficulties encountered in filtering out the lignin in the feces samples collected from the Spanish clover trial.

Negative values were also found for the apparent digestibility of protein in range grass and filaree. Since the protein content of these feeds was low and but little feed was consumed, the total of the undigested material and the nitrogenous waste (metabolic nitrogen) was greater than the intake. This situation would explain the negative coefficients of digestion for protein in these feeds.

Table 3 compares the digestibility of the protein of all three feeds as determined in three ways: first, by the *in vitro* method with hydrochloric acid and pepsin; second, by correcting the apparent digestion for metabolic nitrogen of the feces, obtained by treating the feces with hydrochloric acid and pepsin;

third, by correcting the apparent-digestion figures for metabolic nitrogen, using the formula of Harris and Mitchell.[7]

Table 4 shows the digestible nutrients in 100 pounds of dry matter for the annual range grasses, filaree, and Spanish clover as compared with values found in the previously reported trials with range grasses and filaree.

TABLE 3

Percentage Crude Protein Digested *in Vitro* by Pepsin and Hydrochloric Acid, Compared with *in Vivo* Digestion Corrected for Metabolic Nitrogen in the Feces

Digestibility determined by	Annual range grasses	Filaree	Spanish clover
Digestion with pepsin and hydrochloric acid *in vitro*	43.4	58.1	27.0
Digestion *in vivo*, corrected for metabolic nitrogen in feces by deducting material digestible with pepsin and hydrochloric acid	55.6	48.1	27.0
Digestion *in vivo*, corrected for metabolic nitrogen according to formula of Harris and Mitchell (footnote 7)	61.2	51.2	48.1

TABLE 4

Percentage Digestible Crude Protein and Total Digestible Nutrients in the Dry Matter

Feed	Crude protein*	Nitrogen-free extract	Ether extract	Crude fiber	Total
Annual range grasses	2.5	20.8	0.5	22.0	46.4
Filaree	2.2	30.1	0.9	15.8	50.2
Spanish clover	5.7	31.6	0.7	8.2	47.1
Range grass (reported in 1932)†	....‡	27.0	0.54	22.9	51.1
Filaree (reported in 1932)†	....‡	25.9	0.53	14.0	41.2

* Digestible crude protein is based upon the value found by correcting for metabolic nitrogen in the feces according to the formula of Harris and Mitchell (footnote 7).

† See footnote 5.

‡ No correction for metabolic nitrogen was made in these trials. The apparent digestibility was a negative value.

In these former trials the range grass was cut at a late stage of maturity, but still green; the total digestible nutrients were greater than in the present trial with completely mature dry forage. The filaree in the previous experiment not only was mature, but had been leached by rain; and the nutritive value found was considerably lower than that found in this investigation. Similarly, in the earlier experiments, bur clover decreased markedly in digestibility after the soluble portion was leached out by rain.[8]

DIGESTION TRIALS WITH FLAX HULLS

Flax acreage and production of flax seed for oil has been increasing rapidly in California for several years. Not only has the linseed meal thus obtained increased the supply of protein concentrate, but many thousand tons of hulls

[7] Harris, L. E., and H. H. Mitchell. The value of urea in the synthesis of protein in the paunch of the ruminant. Jour. Nutr. 22:167–81. 1941.

[8] Guilbert, H. R., and S. W. Mead. The digestibility of bur clover as affected by exposure to sunlight and rain. Hilgardia 6:1–11. 1931.

TABLE 5

Percentage Composition of Flax Hulls and of Casein
(Determinations calculated on dry basis)

Feed	Crude protein	Nitro-gen-free extract	Ether extract	Crude fiber	Ash	Lignin	Cellulose	Other carbo-hydrates
Flax hulls	4.64	50.53	1.50	32.95	10.38	21.50	29.10	32.88
Casein (commercial)	90.50	5.25	0.37	.....	3.88	.....	.....	5.25

TABLE 6

Coefficients of Apparent Digestibility of Flax Hulls

Sheep no.	Dry matter	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber	Lignin	Cellulose	Other carbo-hydrates
First trial (flax hulls only)								
5	42.8	16.4	50.5	39.0	30.1	9.8	47.2	62.1
6	47.7	13.6	57.7	44.1	36.2	17.7	51.2	67.9
7	43.5	28.2	50.8	39.2	30.4	12.9	48.6	57.2
8	41.3	23.1	48.8	38.6	27.8	12.5	43.3	56.1
Average	*43.8*	*20.3*	*51.9*	*40.2*	*31.1*	*13.2*	*47.6*	*60.6*
Second trial (flax hulls plus casein)								
5	44.4	21.5	52.7	35.2	32.8	18.9	47.2	59.8
6	41.3	17.4	50.2	34.3	29.2	11.3	42.8	61.0
7	43.0	18.5	51.7	37.4	31.0	15.0	44.7	61.7
8	43.7	24.1	52.5	38.1	32.0	13.1	44.7	64.6
Average	*43.1*	*19.9*	*51.8*	*36.2*	*31.3*	*14.6*	*44.8*	*61.7*

TABLE 7

Percentage Crude Protein of Flax Hulls Digested *in Vitro* by Pepsin and Hydrochloric Acid, Compared with *in Vivo* Digestion Corrected for Metabolic Nitrogen in the Feces

Digestibility determined by	First trial (flax hulls only)	Second trial (flax hulls plus casein)
Digestion with pepsin and hydrochloric acid *in vitro*	59.0	59.0
Digestion *in vivo*, corrected for metabolic nitrogen in feces by deducting material digestible with pepsin and hydrochloric acid	53.1	54.0
Digestion *in vivo*, corrected for metabolic nitrogen according to formula of Harris and Mitchell (footnote 7)	95.6	95.0

have become available for feeding. Since the hulls had already proved to be fairly palatable, their possible feeding value was investigated.

Two digestion trials were run on sheep 5, 6, 7, and 8. In both experiments the preliminary periods and the collection periods lasted 10 days. In the first trial the flax hulls alone were fed; in the second a mixture consisting of 90 per cent hulls and 10 per cent casein. In the first trial the sheep consumed 600 to 800 grams daily without leaving any feed and gained a little weight. In the second trial they consumed 544 to 727 grams of the mixture daily and just maintained weight. They ate the hulls readily.

Table 5 gives the chemical composition of the flax hulls and the casein; table 6 the coefficients of digestibility for the first trial (flax hulls alone) and the second trial (flax hulls plus 10 per cent casein); table 7 the coefficient for digestibility of protein, determined *in vitro* and by correcting for metabolic nitrogen in the feces.

As table 6 shows, the results with the different animals agreed nicely. Evidently, since the average results of the two trials are similar, the addition of casein did not significantly alter the digestibility of the flax hulls.

The digestible nutrients in 100 pounds of flax-hull dry matter are shown in the following tabulation:

	Pounds
Crude protein	4.3
Nitrogen-free extract	26.2
Ether extract	0.6
Crude fiber	10.3
Total digestible nutrients	42.1

The digestible crude protein is based upon the coefficients found by correcting for metabolic nitrogen according to Harris and Mitchell.[9] The total digestible nutrients include digestible ether extract times the usual factor, 2.25.

DISCUSSION

Table 8 gives the results of the four trials, with similar data on some common feeds for comparison. Table 4 and the tabulation of values for flax hulls (p. 8) show the digestible protein and total digestible nutrients in the feeds used in this experiment, based on moisture-free samples and on protein corrected for metabolic nitrogen. Though the corrected protein figure is more nearly the true digestibility, almost all data on feeds have been reported on the basis of apparent digestibility. For that reason, the protein values in table 8 are presented on this basis and also on the basis of approximate natural moisture content of the dried feed.

Judging from the results with the dry, mature annual range grasses and filaree, the total digestible nutrients are high enough so that grazing animals can gain some weight, provided the protein deficiency is corrected by supplemental feeding. The samples used in these and previously reported trials were not sufficiently comparable to show whether or not the digestibility is increased by feeding with an adequate amount of protein. No increase in digestibility of flax hulls resulted from feeding them with a protein supplement (casein). The value of protein supplement on the range is probably that it permits growth or other production and stimulates greater consumption of the range forage. In trials at this station,[10] heifers fed straw alone soon lost their appetites and ate only 6 to 8 pounds daily. Control animals fed 2 pounds of cottonseed meal a day consumed in addition 14 to 16 pounds of straw and gained weight.

[9] Cited in footnote 7.

[10] Unpublished data.

Morrison[11] remarks, "It has been found in numerous investigations that when a ration contains too little protein in proportion to the amounts of easily digested carbohydrates, the digestibility may be seriously reduced." Such an example was cited in the lower digestibility of kafir grain fed in a low-protein diet. The results of the experiments with flax hulls showed no difference with and without the protein supplement. This feed and other low-grade roughages not only are poor in protein, but also contain little readily digested carbohydrate—a fact that may explain the apparent difference between these results and those cited by Morrison.

TABLE 8

Dry-Matter, Digestible-Protein, and Total-Digestible-Nutrient Content of the Feeds Used in These Trials Compared with Some Common Feeds

Feed	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds	
		Crude protein	Total
	pounds	*pounds*	*pounds*
Alfalfa hay, all analyses*	90.4	10.6	50.3
Bur clover (reported in 1932)†	90.0	11.8	56.5
Oat hay*	88.0	4.5	46.3
Barley straw*	90.0	0.9	44.5
Wheat straw*	90.1	0.8	35.7
Mature, dry annual range grass	90.0	....‡	39.5
Mature, dry broad-leaf filaree	90.0	....‡	43.3
Green Spanish clover (dried)	90.0	1.9	39.1
Flax hulls	90.0	0.8	34.7

* Morrison, F. B. Feeds and feeding. 20th ed. Appendix table 1. The Morrison Publishing Co., Ithaca, New York. 1936.

† See footnote 5.

‡ The apparent digestibility was a negative figure because more protein (nitrogen) was excreted in the feces than was contained in the small quantity of forage consumed.

The flax hulls were comparable in value with poor straw. They were, however, rather palatable. If supplemented with adequate protein and fed with other feeds, they should be useful in maintaining mature stock. They would be of doubtful value in any fattening ration unless limited quantities were used to improve the physical consistency of the feed or possibly to counteract the excessive laxative effect of very leafy legume hay.

The Spanish clover cut green at an advanced stage of maturity was surprisingly low in digestibility. Because of the higher protein content it might be expected to have a distinctly beneficial effect when eaten along with the protein-deficient grasses and herbs. The digestibility, however, was so low, even after correction for metabolic nitrogen, that the plant at this stage has only limited value as a protein source. The total digestible-nutrients content was lower than that of the dried grass and filaree. Though the value doubtless is higher at earlier stages, the plant is neglected by cattle as long as other green forage is plentiful.

The digestibility of lignin, cellulose, and "other carbohydrate" fractions ranged from low to high in the order named for each feed. In predicting feed

[11] Morrison, F. B. Feeds and feeding. 20th ed. 1050 p. The Morrison Publishing Co., Ithaca, New York. 1936.

value from chemical analyses, these determinations are more significant than crude-fiber and nitrogen-free-extract determinations, which do not separate fractions of roughages having characteristically different digestibilities. In general the digestibility of all nutrients decreased as the lignin content of the feeds increased.

In vitro pepsin and hydrochloric acid digestion of the feed has been compared with the digestion coefficients obtained through correction of apparent digestibility by two methods of estimating metabolic nitrogen. Judging from the comparison, the *in vitro* method is useful in predicting relative values in this type of feed. Including this analysis along with lignin and cellulose determinations is an improvement over conventional analysis for predicting feed value.

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