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THE DIGESTIBILITY OF BUR CLOVER AS AFFECTED BY EXPOSURE TO SUNLIGHT AND RAIN

H. R. GUILBERT[1] AND S. W. MEAD[2]

The principal forage plants of California foothill and valley ranges are annuals.[3] They germinate with the coming of the fall rains and make, during the winter, an amount of growth that varies according to moisture and temperature conditions. From February to May is usually the period of greatest growth. When the rains cease and moisture is depleted, the forage matures and dries. Stock is then either maintained on the dry feed or moved to summer ranges in the high mountains. In the latter case, the stock is brought to the lower ranges in the early fall and subsists on the old dry feed until rains bring on new forage.

The changes in the plants from the early vegetative stage to the dried condition involve marked changes in chemical composition and nutritive value. After drying, the feed is subjected to the processes of weathering.

Studies by Woodman and others[1, 2, 3] on the nutritive value of pasture have shown that young pasture grass is in digestible composition a "watered concentrate" rather than a roughage. They found that 70 per cent of the organic matter was digestible and that the small amount of fiber which it contained was 80 per cent digestible. The immature grass contained approximately 20 per cent digestible protein with a nutritive ratio of about 1:3. As plants approach

[1] Assistant Animal Husbandman in the Experiment Station.

[2] Associate Animal Husbandman in the Experiment Station.

[3] The most common of the grasses are several species of brome, wild oats (*Avena fatua*), fescue grass (*Festuca megalura*), and foxtail (*Hordeum murinum*). Bur clover (*Medicago hispida*) and alfilaria (*Erodium* sp.) are found on the better ranges. Salt grass (*Distichlis spicata*), a perennial, is also important in some areas.

maturity, the percentage of nitrogen-free extract and fiber increases, while the protein decreases. The result is a widening of the nutritive ratio and a decrease in digestibility.

Cattle do not graze extensively on green bur clover when other forage such as grasses and alfilaria are present in adequate amounts. As soon as the forage matures and dries, however, they show a decided preference for bur clover.

A high forage value is generally recognized in bur clover ranges during the first few weeks after the feed has cured, and the final finish is usually made by fattening cattle during this period. A late rain, coming after the feed is cured, is disastrous from the standpoint of finishing cattle without supplement; and under such conditions it has, in many cases, been found difficult even to maintain breeding stock.

The most efficient utilization of range forage is a problem involving the proper supplementing of this feed in such a way as to keep the animals supplied at all times with a well balanced diet. To accomplish this it is necessary to have definite information on the changes in composition of the feed and its effect on the nutrition of the animal. Since bur clover is an important forage species which maintains good feeding qualities in the cured condition, the effect of weathering upon its nutritive value is of particular interest.

DIGESTION EXPERIMENTS WITH BUR CLOVER

Approximately one acre of a nearly pure stand of bur clover was cut May 17, 1927, the only contamination being a few star thistles. Most of the burs were still green at the time of cutting, but the seeds were well formed and most of them were yellow in color after the forage had been dried.

Immediately after cutting, the clover was spread out in a thin layer on a clean, concrete pavement and exposed to direct sunlight. It dried rapidly, and on the following day a portion was piled in small cocks for further curing. On the fourth day a rain storm, lasting a few minutes, necessitated the placing of this material in larger piles to minimize wetting. Only the tops and bottoms of these piles were wet, and apparently the shower did little damage. The following day the clover was turned and allowed to cure in large cocks until the seventh day after cutting, at which time it was chopped, thoroughly mixed, sacked, and stored in a dark loft. This portion was bright green in color and was designated as bur clover No. 1.

The remainder of the clover was allowed to dry and bleach in the sun. It was spread out in a thin layer and was mixed and turned at intervals of a few days in order to expose all the material to the sun and simulate field conditions as nearly as possible. During this period (May 17 to June 7) two showers totaling 0.31 of an inch of rain fell. On June 7 another rain storm threatened. One-half of the clover was therefore put under cover and later chopped, mixed, sacked, and stored. This was designated as bur clover No. 2. In contrast to bur clover No. 1, it was brown in color.

This second rain, which amounted to 0.47 inch, fell on the clover remaining after lot 2 had been removed. The water which drained from the clover was decidedly brown in color. The leaching effect of this rain was more noticeable than that of the two previous lighter showers. After the rain, this material was left exposed for an additional 14 days; then it was chopped, mixed, sacked, and stored. It was designated as bur clover No. 3. The treatment of each of the lots may be briefly summarized as follows:

Bur clover No. 1. Cured for one day in a thin layer, then cured in cocks for six days.

Bur clover No. 2. Exposed in a thin layer for 21 days, during which time it was wet twice by rain totaling 0.31 inch.

Bur clover No. 3. Exposed in a thin layer for 34 days, during which time it was wet three times by rain totaling 0.78 inch.

The original plan was to study the influence of varying periods of exposure to sunlight, upon digestibility. The late rains provided an opportunity to study the influence of this additional factor upon the feed, but it was unfortunate that the study of lot 2 was complicated by wetting, as it eliminated the possibility of comparing directly the relative influence of exposure to sunlight and to rain.

During March, April, and May, 1928, digestion experiments were conducted on these three lots of bur clover. The same five wether sheep were used in each of the trials. They were fed an amount of bur clover which was calculated to be sufficient for maintenance, the value assumed being similar to that of average alfalfa hay. The methods used in conducting these experiments were fully discussed in an earlier publication[4] and are summarized here.

The animals were placed in individual box stalls 4 feet by 8 feet, equipped with mangers so constructed as to prevent any possible loss of feed. The feces were collected by means of rubber-lined sacks attached to each animal.

The preliminary feeding period was 10 days and the collection period 15 days.

An amount of bur clover sufficient to last throughout a digestion trial was thoroughly mixed and spread out on a clean concrete floor. The individual feeds for the entire period were then weighed out into paper bags. The bags were labeled designating the animal to which the feed contained was to be given. To obtain a sample for chemical analysis a large quantity was taken and reduced to about ¼ bushel by mixing and quartering. This amount was then ground in a hammer mill, thoroughly mixed, and the final sample for chemical analysis taken from the fine material. A sample for moisture determination was taken before grinding.

The collection bags were emptied twice daily. The feces were immediately weighed and aliquot portions of the feces of each animal were placed in glass mason jars which had been previously rinsed in a 10 per cent alcoholic thymol solution. In addition, powdered thymol was sprinkled over the feces after they were transferred from the scales to the jar to the amount of 5 grams to each jar. The jars were immediately placed in a refrigerator where they were maintained at a temperature varying from 28 to 35 degrees Fahrenheit. At the end of the collection period the contents of the several jars representing the total feces collected from each animal were thoroughly mixed, ground, remixed and sampled for chemical analysis.

The data from the digestion trial with bur clover No. 1 are given in tables 1, 2, and 3.

TABLE 1

TOTAL FEED CONSUMED AND TOTAL FECES COLLECTED

Sheep No.	Bur clover No. 1, grams	Feces grams
137	9,600	7,457.5
139	12,000	9,722.5
717	10,500	8,589.5
138	7,500	5,349.5
135	11,700	10,556.0

TABLE 2

CHEMICAL ANALYSES OF FECES AND OF BUR CLOVER NO. 1

Feces	Dry matter per cent	Crude protein per cent	Nitrogen-free extract per cent	Ether extract per cent	Crude fiber per cent
Sheep No. 137	38.85	5.00	13.88	1.63	12.72
Sheep No. 139	38.01	4.68	14.73	1.60	11.56
Sheep No. 717	38.46	5.22	14.43	1.70	11.69
Sheep No. 138	43.34	5.63	17.15	1.66	13.11
Sheep No. 135	35.12	4.32	13.71	1.21	11.19
Bur Clover No. 1	86.62	15.34	40.65	2.89	19.90

TABLE 3

COEFFICIENTS OF DIGESTIBILITY OF BUR CLOVER No. 1

Sheep No.	Dry matter	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber
137	65.16	74.68	73.48	56.19	50.35
139	64.45	75.18	70.64	55.14	52.93
717	63.68	72.27	70.96	51.88	51.94
138	64.31	73.82	69.91	59.03	53.07
135	63.42	74.59	69.57	62.22	49.27
Average	*64.20*	*74.11*	*70.91*	*56.89*	*51.51*

The data from the digestion trial with bur clover No. 2 are given in tables 4, 5, and 6.

TABLE 4

TOTAL FEED CONSUMED AND TOTAL FECES COLLECTED

Sheep No.	Bur clover No. 2 grams	Feces, grams
137	8,353.0	7,072.0
139	11,866.0	10,355.0
717	9,667.0	8,398.5
138	7,387.0	5,996.5
135	11,491.0	10,300.0

TABLE 5

CHEMICAL ANALYSES OF FECES AND OF BUR CLOVER No. 2

Feces	Dry matter per cent	Crude protein per cent	Nitrogen-free extract per cent	Ether extract per cent	Crude fiber per cent
Sheep No. 137	41.16	5.39	16.93	1.47	12.69
Sheep No. 139	40.28	5.36	16.57	1.48	12.22
Sheep No. 717	41.97	6.28	16.88	1.58	12.22
Sheep No. 138	44.66	6.03	17.89	1.66	13.82
Sheep No. 135	39.98	5.23	16.28	1.46	12.22
Bur Clover No. 2	87.48	15.18	40.48	2.22	21.97

TABLE 6

COEFFICIENTS OF DIGESTIBILITY OF BUR CLOVER No. 2

Sheep No.	Dry matter	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber
137	60.17	69.88	64.59	43.91	51.10
139	59.82	69.19	64.28	41.80	51.46
717	58.32	64.06	63.77	38.16	51.68
138	58.56	67.75	64.12	39.33	48.94
135	59.04	69.12	63.95	41.04	50.14
Average	*59.18*	*68.00*	*64.14*	*40.85*	*50.66*

The data from the digestion trial with bur clover No. 3 are shown in tables 7, 8, and 9.

TABLE 7

TOTAL FEED CONSUMED AND TOTAL FECES COLLECTED

Sheep No.	Bur clover No. 3 grams	Feces, grams
137	8,700.0	8,181.0
139	12,000.0	12,658.5
717	9,750.0	8,808.5
138	7,500.0	6,589.5
135	11,700.0	11,312.0

TABLE 8

CHEMICAL ANALYSES OF FECES AND OF BUR CLOVER NO. 3

Feces	Dry matter per cent	Crude protein per cent	Nitrogen-free extract per cent	Ether extract per cent	Crude fiber per cent
Sheep No. 137	41.78	5.98	16.90	1.60	12.62
Sheep No. 139	38.53	5.57	15.72	1.45	11.49
Sheep No. 717	45.02	7.08	18.39	1.82	12.41
Sheep No. 138	46.43	6.69	18.69	1.77	13.99
Sheep No. 135	41.99	5.96	17.06	1.53	12.51
Bur Clover No. 3	91.15	16.28	40.87	2.02	25.04

TABLE 9

COEFFICIENTS OF DIGESTIBILITY OF BUR CLOVER NO. 3

Sheep No.	Dry matter	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber
137	56.90	65.46	61.12	25.51	52.61
139	55.41	63.91	59.43	24.28	51.60
717	55.38	60.71	59.35	18.60	55.23
138	55.25	63.90	59.82	23.02	50.91
135	55.46	64.60	59.64	26.77	51.70
Average	*55.68*	*63.72*	*59.87*	*23.64*	*52.41*

Tables 3, 6, and 9 show the percentage of each ingredient in the three lots of bur clover digested by the animals. As separate data were obtained from each animal, the average represents the results of five separate trials. The variation of individual sheep from the average of each trial was very small. The greatest variation is found in the percentage of ether extract digested, which is the nutrient present in smallest amounts and is therefore subject to the greatest amount of experimental error. The variation of the ether extract from the average is not very great and has little influence upon the total digestible nutrients in the feed.

There was some variation in the moisture content of the three lots of bur clover, and therefore a comparison can best be made upon the dry basis. The chemical composition of the three lots on the dry basis is given in table 10.

TABLE 10

PERCENTAGE COMPOSITION OF BUR CLOVERS 1, 2, AND 3; DRY BASIS

Bur Clover No.	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber	Total ash	CaO	P_2O_5
1	17.71	46.93	3.34	22.97	9.05	.....	0.72
2	17.35	46.27	2.54	25.11	8.72	1.24	0.68
3	17.86	44.84	2.22	27.48	7.61	1.30	0.67

The difference in composition between bur clover No. 1 and No. 2 does not appear very significant except for the lower ether extract and the slightly higher crude fiber in No. 2. Perhaps the processes involving the change in color of the chlorophyll and loss of aromatic compounds may have affected the amount of ether-extractable material.

Bur clover No. 3 is slightly higher in protein than No. 1 and lower in nitrogen-free extract, ether extract, and total ash. The decrease in nitrogen-free extract and ash, with the corresponding increase in crude fiber, may be taken as indicative of leaching.

The average coefficients of digestibility of each nutrient in the three lots of bur clover are shown in table 11.

TABLE 11

AVERAGE COEFFICIENTS OF DIGESTIBILITY

Bur Clover No.	Dry matter	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber
1	64.20	74.11	70.91	56.89	51.51
2	59.18	68.01	64.14	40.85	50.66
3	55.68	63.72	59.87	23.64	52.41

Table 11 shows that from bur clover No. 1 to No. 3 there was a progressive decrease in digestibility of all nutrients except crude fiber.

The extent to which the decrease in digestibility could be attributed relatively to leaching by rain or to changes resulting from other factors was not known, since the difference in chemical composition was not very great. It is possible, however, that considerable amounts of each nutrient, with the exception of crude fiber, might have been extracted and still not have changed very greatly the composition of the residue. Since part of the soluble material had already been removed from bur clovers 2 and 3, it was expected that if samples

of all three lots were subjected to leaching under identical conditions in the laboratory that the difference in amount of material extracted would indicate the extent of the loss by rain, providing other factors such as exposure to sunlight and air had not changed the solubility of the nutrients. Accordingly, approximately 400-gram samples each of bur clovers 1, 2, and 3 were taken for the leaching experiments. The burs were separated from the stems and leaves, and the percentage of each was determined. The percentage of burs was 31.4 per cent, 30.8 per cent, and 31.2 per cent for samples 1, 2, and 3, respectively. The stems and leaves were thoroughly mixed and divided into two approximately equal portions. Each sample was then made up to exactly 30 per cent burs and 70 per cent leaves and stems. One portion was used for analysis, the other was leached. The weights of samples leached were 172 grams, 168 grams, and 182 grams respectively, for bur clovers 1, 2, and 3. The samples were placed in soil percolators for one hour with two liters of distilled water; they were then washed twice with one-liter portions of water, and the final volume of extract was made up to four liters. The extract was first filtered with suction through linen, and the portions used for analysis were filtered through filter paper to remove any solids in suspension. The percentage of the total dry matter extracted was determined and found to be 19.94, 15.97, and 11.73 for bur clovers 1, 2, and 3, respectively.

In order to ascertain whether exposure to sunlight and air without leaching would bring about chemical changes which would decrease the amount of soluble material, a quantity of bur clover was collected and dried by spreading out in a thin layer on canvas for 2½ days. One-half was then stored and the other allowed to bleach in the sun for 40 days. It was protected against loss of leaves by screens and was taken indoors when the weather was inclement. At the end of this time it was very dry and thoroughly bleached. Duplicate 100-gram samples of each lot were then leached under identical conditions. No difference was found in the amount of total solids extracted.

In another experiment in which samples of alfalfa meal were extracted with water after exposure to irradiation from a quartz mercury vapor lamp for 2 hours at a distance of 18 inches, no difference in water soluble material was found. It was therefore concluded that exposure to light and air did not effect the solubility of the nutrients in forage and that the difference found between the different lots of bur clover was caused by the previous leaching by rain.

The difference in digestible organic matter per 100 pounds of dry matter between bur clover No. 1 and No. 2 was 4.89 pounds. The difference between No. 1 and No. 3 was 6.95 pounds. The amount of organic matter indicated to have been lost from bur clover No. 2 and No. 3 through the action of rain was 3.2 and 6.5 pounds, respectively. If this soluble organic matter is assumed to be highly digestible the greater part of the difference in digestibility can be accounted for by the loss of these soluble constituents.

The digestible nutrients in 100 pounds of dry matter in bur clovers 1, 2, and 3 are shown in table 12.

TABLE 12

POUNDS OF DIGESTIBLE NUTRIENTS IN 100 POUNDS OF DRY MATTER

Bur clover No.	Crude protein	Carbohydrate	Fat	Total*	Nutritive ratio
1	13.13	45.11	1.89	62.49	1:3.68
2	11.80	42.40	1.04	56.54	1:3.79
3	11.41	41.25	0.52	53.83	1:3.72

* Total includes fat times the factor 2.25.

The total digestible nutrients decreased from 62.5 in bur clover No. 1 to 56.5 and 53.8 in bur clover No. 2 and No. 3, respectively. This represents a decrease in total food value of 9.54 per cent in No. 2 and of 13.8 per cent in No. 3, compared to bur clover No. 1. The ratio of protein to carbohydrate and fat remained practically unchanged and is relatively narrow.

Bur clover No. 2 and No. 3 were apparently less palatable to the sheep than was bur clover No. 1. Upon changing from the latter to No. 2 it was found necessary to reduce slightly the quantity fed in order to induce the sheep to consume the entire ration.

In spite of a significant decline in total digestible nutrients, bur clover No. 3 was still comparable in digestible composition to average alfalfa hay.

Since the bur clover was cured on concrete floors, where it was possible to recover all of the burs, stems, and leaves, each lot was representative of the entire plant as it occurred in the field. The chemical composition of the burs as compared with the stems and leaves is shown in table 13.

With the exception of the ash there is no very significant difference in the composition of burs and of stems and leaves. It would, therefore, seem doubtful that the total feed value of the burs is any greater than that of the stems and leaves combined, especially as large numbers of seeds were observed to be practically unchanged in the feces.

TABLE 13

PERCENTAGE COMPOSITION OF BURS AND OF STEMS AND LEAVES; DRY BASIS

	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber	Total ash
Burs	15.12	51.42	3.33	23.78	6.35
Stems and leaves	16.33	47.11	2.36	23.81	10.39

The net energy value in therms per 100 pounds dry matter for each of the three lots of bur clover has been computed according to the method of Armsby[5] and is given below:

Bur clover No. 1—43.18 therms.
Bur clover No. 2—35.35 therms.
Bur clover No. 3—32.06 therms.

According to Armsby the maintenance requirement for a 1,000-pound steer is 6 therms of net energy daily, and the average requirement for each pound of increase during fattening is 3.25 therms. The significance of the difference in digestible composition of the three lots of bur clover may be demonstrated by a hypothetical case wherein a 1,000-pound steer eats 25 pounds of bur clover daily. The gain expected from each of the lots of bur clover has been computed and is shown in table 14.

TABLE 14

COMPUTED NET ENERGY VALUE OF THE FEED AND GAIN IN LIVE WEIGHT FROM THE CONSUMPTION OF 25 POUNDS OF DRY MATTER DAILY

Bur clover No.	Total net energy therms	Required for maintenance therms	Available for gain therms	Computed gain pounds
1	10.80	6	4.80	1.47
2	8.84	6	2.84	0.87
3	8.01	6	2.02	0.62

If the total dry matter consumed daily in each case were limited to 20 pounds, the computed gains would be approximately 0.8 pound, 0.3 pound, and no gain, respectively, for bur clovers 1, 2, and 3.

Table 14 shows that even a comparatively small change in total feed value reduces the margin of energy above the maintenance requirement so that gains are seriously affected.

The effect of excessive exposure and of rain is probably minimized in this experiment because all the burs and leaves were saved. On the range there undoubtedly would be a heavy loss of leaves because of the beating effect of the rain and because of the tendency of the leaves subsequently to become brittle, easily pulverized, and hence lost by being mixed with dirt or blown away by the wind. The loss of leaves would probably cause a marked decline in protein, ash, and

digestible carbohydrate. Table 15 from Henry and Morrison[6] shows the relative composition of alfalfa hay, leaves, and stems. The difference in composition probably holds true in a general way for bur clover leaves and stems.

TABLE 15

THE PERCENTAGE COMPOSITION OF ALFALFA HAY, LEAVES AND STEMS

	Water	Crude protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash
Alfalfa hay	8.6	14.9	37.3	2.3	28.3	8.6
Alfalfa leaves	6.6	22.5	41.2	3.4	12.7	13.6
Alfalfa stems	5.6	6.3	27.9	0.9	54.4	4.9

Table 15 shows that the alfalfa leaves contained 22.5 per cent protein as compared to 6.3 per cent in the stem. The leaves were also much higher in easily digestible carbohydrate and very much higher in ash. This indicates that any condition which results in loss of leaves would cause a decided decrease in forage value.

SUMMARY

Bur clover, in common with other legumes, is rich in protein and has a narrow nutritive ratio. Even when cut in advanced stages of maturity it has a higher coefficient of digestibility than most hays.

Weathering of bur clover, which included exposure to rain, resulted in a decrease in digestibility of each nutrient except crude fiber. Evidence has been presented which indicates that the loss of soluble constituents caused by rain may have been responsible for the greater part of the decrease in digestibility.

The bleaching and leaching processes apparently decreased the palatability of the bur clover used in the digestion experiments.

The significance of the decrease in digestibility on gains in live weight has been discussed in the text.

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The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.

5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.

6. A Study of Deciduous Fruit Tree Rootstocks with Special Reference to Their Identification, by Myer J. Heppner. June, 1923.

7. A Study of the Darkening of Apple Tissue, by E. L. Overholser and W. V. Cruess. June, 1923.

8. Effect of Salts on the Intake of Inorganic Elements and on the Buffer System of the Plant, by D. R. Hoagland and J. C. Martin. July, 1923.

9. Experiments on the Reclamation of Alkali Soils by Leaching with Water and Gypsum, by P. L. Hibbard. August, 1923.

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11. Studies on the Effects of Sodium, Potassium, and Calcium on Young Orange Trees, by H. S. Reed and A. R. C. Haas. October, 1923.

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16. The Moisture Equivalent as Influenced by the Amount of Soil Used in its Determination, by F. J. Veihmeyer, O. W. Israelsen and J. P. Conrad. September, 1924.

17. Nutrient and Toxic Effects of Certain Ions on Citrus and Walnut Trees with Especial Reference to the Concentration and Ph of the Medium, by H. S. Reed and A. R. C. Haas. October, 1924.

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19. The Relation of the Subcutaneous Administration of Living Bacterium abortum to the Immunity and Carrier Problem of Bovine Infectious Abortion, by George H. Hart and Jacob Traum. April, 1925.

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