Some Effects of the Species and Stage of Maturity of Plants on the Forage Consumption of Grazing Steers of Various Weights

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By W. P. Garrigus and H. P. Rusk[a]

MORE LAND in the United States is used for pasture than for all other farm crops grown. Fertile, well-managed pastures have always been recognized as an economical source of feed, and recently have commanded much attention as an effective means of conserving soil resources and preventing erosion. Notwithstanding the well-established importance of pasture in American agriculture, very little is known about the effects of different plant and animal variants on the forage consumption of grazing animals. In fact, practically no accurate data are available on the basic problem of amounts of various pasture forages consumed by different species of grazing animals. Many estimates of the relative palatability of different species of pasture plants have been published; but they have been only estimates, based on visual observations or other equally unreliable methods of measuring forage consumption.

The lack of accurate information on the actual amounts of forage consumed by grazing animals has been generally recognized by investigators who have studied the problem.[10, 35, 39, 40, 51*] Apparently the reason why such a basic question has been left unanswered is that no practical means of accurate measurement under actual grazing conditions has heretofore been devised. Even the most elaborate and carefully conducted studies have involved too many approximations and other probable sources of error.

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The authors are especially indebted to H. H. Mitchell, Chief in Animal Nutrition, for generous cooperation thruout the course of the experiments; to W. L. Burlison, Chief in Crop Production, for many helpful suggestions on the agronomic phase of the investigation; and to W. M. Dawson, formerly Assistant in Animal Husbandry, and L. J. Norton, Chief in Agricultural Marketing, for verifying the statistical methods employed in interpreting and testing reliability of the data and conclusions.

All of the data in this bulletin, except the data for the grazing season of 1935, were submitted by the senior author to the Graduate School of the University of Illinois, June, 1935, in partial fulfillment of the requirements for the degree of doctor of philosophy in animal husbandry.[20*]

*These numbers refer to literature citations on pages 506 to 508.

The method[a] (described on pages 450 to 458) used in the present investigation is apparently much more accurate than the methods which have been used in other forage-consumption investigations. It is unique in pasture studies, but it is based on principles that have been definitely established by investigators in animal nutrition.

Forage intake rather than nutritive value of the forages was emphasized in this investigation. An attempt was made to measure by precise methods the exact consumption of several species of forages in different stages of maturity by freely grazing steers of different ages and weights. It is realized that the data are not extensive enough to afford conclusive comparisons of the different forages; but they do demonstrate the accuracy of the method, and suggest that the further use of it in other investigations of this sort, and the application of it to other phases of pasture investigation, may prove valuable.

ADVANTAGES AND DISADVANTAGES OF EARLIER METHODS OF MEASURING FORAGE CONSUMPTION

The following methods of determining the forage consumption of animals while grazing are the only ones that a search of the literature on the subject has disclosed. An attempt is made here to weigh the advantages and the disadvantages of each experimental method. Apparently none combines the accuracy and practicability that are necessary for successfully accomplishing its object.

Clipping Method

Description of Method.—By this method, the one generally used heretofore in studies of forage consumption by grazing animals, the total forage offered to an animal on a given experimental pasture area is estimated, either by cutting sample strips across the experimental area or by clipping a similar area close by. When this estimate is made the animal is permitted to graze the experimental area for twenty-four hours; and the forage remaining is then clipped and weighed. The difference between this remaining amount of forage and the estimated total is considered to be the amount consumed by the grazing animal.

A logical way to check the accuracy of data on forage consumption

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[a]The procedure used in this investigation was developed and tested in connection with studies reported in "A Method for Accurately Determining the Forage Consumption of a Grazing Steer," submitted by the senior author of this bulletin to the Graduate School of the University of Illinois, 1933, in partial fulfillment of the requirements for the degree of master of science.

secured by this old method is to compare the energy content of the forage that is reported to have been consumed with the energy requirements for maintenance and production of the animals used. Three such determinations have been found in the literature,[49, 50*] but accurate records of gains made or dry matter consumed are not reported and the adequacy of the reported rations consumed cannot be accurately determined. Rough estimates indicate that the amount of forage reported to have been consumed would have barely provided, or in some cases failed to provide, even a maintenance ration for the animals in question.

Sources of Error.—The sources of error inherent in this method become obvious upon critical examination. Some of them are listed below in the approximate order of their importance.

1. Lawn mowers, ordinarily used in clipping, do not cut the grass on the sample areas before grazing as close to the ground as they clip the grazed areas. When the amount of forage offered is being determined, the grass is relatively tall and, as a consequence, the lawn mower cuts at a high level. When the grazed area is cut to determine the amount of forage not consumed, the grass is relatively short and thin, and the mower therefore cuts at a considerably lower level than before. This obviously introduces a large error, causing the forage consumption to be underestimated.

2. Animals often graze more closely to the ground than the mower cuts. Frequently they pull the grass up by the roots, or break it off near or slightly under the surface of the ground. This difference between clipping and grazing causes the forage consumption to be considerably underestimated.

3. When sample strips to determine the amount of forage offered have been cut from the area to be grazed, no attempt has been made to estimate the growth of the grass during the grazing period. The growth that naturally occurs causes the amount of forage consumed to be underestimated. The error thus introduced might range from 5 to as much as 10 percent of the forage consumption, depending on the rate of growth of the grass and the percentage of the forage offered that is consumed.

4. The conditions under which the experimental animal is kept while his normal forage consumption is being sought have often been far from normal. Animals naturally like the company of other animals of like species, and being shut up in a small cage in the middle of a lot without company may cause a grazing animal to be restless and to graze less than it would if it were contented. It is possible that this gregarious instinct can be overcome if a preliminary period of sufficient length is used to accustom the animal to the experimental conditions before the collection of data is started.

In the second place, an animal naturally tends to roam more or less as it grazes, and consequently confining it to a small area may materially reduce forage consumption.

Finally, shade usually is lacking in the small cages used with this old method. The animal is therefore exposed to the sun during the heat of the day and, as a result, may be restless and nervous. During extremely hot weather it may become so heated as to have a definitely smaller than normal appetite.

5. Accurate determination of the amount of forage not consumed is hindered by the droppings of the experimental animal and the trampling down of the grass.

6. Cutting the sample-yield areas and the grazed experimental areas at different times introduces a large error unless accurate dry-matter determinations are made. The grass may be wet at one time and dry at the other. In the present investigation external moisture on the forage often reduced the percentage of dry matter by 15 to 30 percent.

7. Lawn mowers do not operate successfully with forage plants as tall as many of the common pasture plants normally are when grazed. But other means than the use of lawn mowers for determining the forage offered and not consumed are also inaccurate because of the difficulty of maintaining a fixed level of cut.

8. The use of the yield of an adjacent plot to estimate the amount of forage offered in the experimental plot introduces an error which necessitates repetition of the trials to insure a high degree of accuracy.

9. Any unevenness of forage in the grazed plot introduces an error in weights of the clippings.

Comparison of Clipping Method With Method Used in This Study.—A careful comparison of the old clipping method with that used in the present study was made early in this series of investigations.[19*] A 535 pound Hereford steer (Fig. 1) in moderate flesh was allowed to graze for eight successive days on a pasture composed chiefly of mixed clovers and a small percentage of water grass and weeds. The steer was confined to an area of four square rods by high plank-and-wire panels which were moved to a new location daily. Before data were taken a suitable preliminary period elapsed during which the steer became accustomed to the experimental conditions. During the eight days when data were taken the area to be grazed was carefully sampled by mowing strips across the plot connecting the opposite sides at their midpoints, and the yield of the area left to be grazed was computed from the yield of these sample strips. The steer was allowed to graze each area for 24 hours, after which the plot was mowed over its entire area, and the difference between the amounts of forage calculated to have been present on the plot before and after grazing was taken to be the amount consumed by the steer. Care was taken to eliminate all avoidable errors in sampling and collecting the grass. Dry-matter determinations were made on all samples.

The steer's average daily consumption during the eight successive days was estimated by the above procedure to have been 17.8 pounds of green forage, or 5.34 pounds of dry matter per day. But this amount provided approximately 4,592 Calories or only 83 percent of the calculated maintenance requirement of the steer, approximately 5,508 Calories per day. (See pages 451 to 453 for details of calculations.)

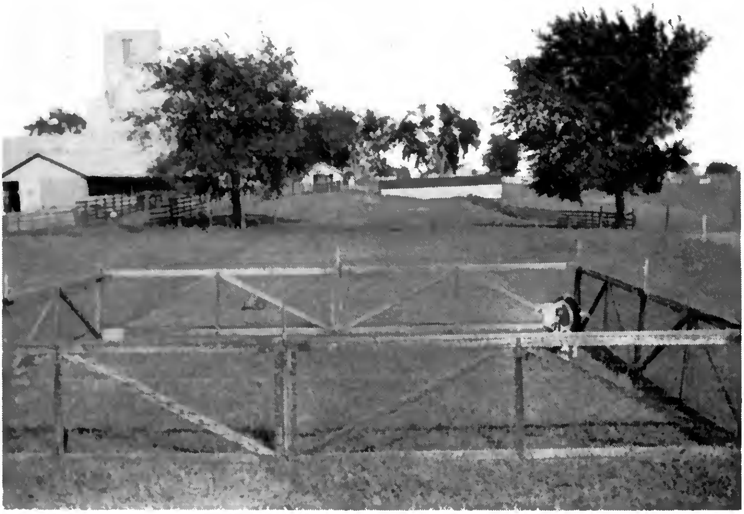

FIG. 1.—STEER B (PUREBRED HEREFORD) IN ENCLOSURE WHERE OLD CLIPPING METHOD WAS COMPARED DIRECTLY WITH METHOD USED IN PRESENT INVESTIGATION

The new method (described in detail on pages 450 to 458) was used simultaneously with the old method, on the same steer grazing the same forage and during exactly the same period. The results obtained by the new and old methods were therefore directly comparable. The consumption was calculated by the new method to have been 12.3 pounds of dry matter per day, or 192 percent of the steer's maintenance requirement. This consumption was 2.3 times as large as that estimated by the old method.

The errors previously listed as being inherent in the old clipping method were observed to be present in this critical study. According to the results obtained with the new method, the total effect of these errors in this test resulted in a net error of approximately 57 percent in the forage consumption of the steer.

Erizian's Method

An interesting but somewhat laborious method of determining the forage consumption of grazing animals has been devised and used by Erizian[11*] for pasture studies in Germany.

Description of Method.—The animal is weighed at the beginning and at the end of the grazing period. During the grazing period the liquid and solid excreta are caught and weighed by attendants, and the insensible loss in body weight is calculated with the aid of previously determined constants. The forage consumption during this period is taken to be the final weight of the animal, plus the weight of the excreta and calculated insensible loss, minus the initial weight of the animal.

The accuracy of this method is primarily dependent on the accuracy with which the total insensible loss during the grazing period can be estimated. To determine this loss for resting, walking, and grazing, the animal was weighed before and after known periods during which he was engaged solely in one of these activities. The loss due to grazing was estimated by placing the animal in a crate with a piece of sod and allowing it to graze for a definite period. Weights were taken before and after grazing and the insensible loss per unit of time was determined.

Sources of Error.—Erizian's method is interesting in that it uses a more or less scientific approach to the problem. But certain disadvantages and sources of error are nevertheless apparent. Some of the more important ones are the following:

1. This method gives an approximation of the total weight of forage consumed during the grazing period. The percentage of dry matter in the forage and consequently the total amount of dry matter consumed have not been and cannot be accurately determined by Erizian's method. Any grazing animal practices selective grazing and therefore the composition of the forage he consumes cannot be determined unless individual digestion coefficients plus fecal collections and analyses are employed.

Not only do different species and parts of plants have varying dry-matter contents, but also the percentage of dry matter contained in a growing forage frequently varies during the day because of the presence of varying amounts of rain or dew on the external surfaces. Therefore, even if this method were to give accurate measurements of the total weights of forage consumed, it could not give accurate measurements of the total dry-matter consumption, which are necessary in any accurate investigation of this nature.

2. The accurate determination of rates of insensible loss during periods of walking, resting, and grazing would require the use of much more delicate weighings and scientific technique than would be practical in most pasture research projects of this nature. Determination of the insensible loss resulting from grazing activity offers a good example of the type of error which might be involved. The insensible loss during at least several hours of normal grazing must necessarily be determined before an average rate could be arrived at. During this period a large amount of sod would have to be dug up, weighed, and offered to the animal. This would obviously introduce opportunities for significant errors caused by uncontrolled evaporation of moisture from the sod.

3. A third serious criticism of this method would be that animals can hardly be considered as being under normal grazing conditions when constantly followed around day and night by attendants, carrying scoops and pails, who hurriedly approach at the first sign of defecation or urination by the experimental animal.

In general it may be said that Erizian's method can determine only the total weight of forage eaten by the animal and cannot determine what is practically essential to the accuracy of the experiments, the dry-matter intake. The normalcy of grazing conditions must necessarily be violated in the operation of this method. Moreover, the excessive expenditure for labor and equipment render the method of doubtful practical value.

A grazing cow such as Erizian used probably would consume at least ten pounds of green forage an hour.[21*] Evaporation from the square rod of sod necessary to provide this amount of forage would be determined by temperature, humidity, and velocity of air currents. An average figure for such evaporation based on experimental evidence[48*] is approximately 2 pounds per hour per square rod.

It is probable that the total insensible loss of a 1,000-pound cow would not be more than 10 to 15 percent of her forage intake.[30*] Gross errors in calculating the insensible loss, however, would impair considerably the accuracy of the findings arrived at by the use of this procedure.

A Method Based on Calculated Nutrient Requirement

To estimate the forage consumption of grazing animals from the calculated nutrient requirements for production and maintenance[25*] has been a common practice among pasture investigators. The requirements of the animals have been based on not-too-accurate average values, usually taken from feeding standards. The value of the forage for meeting these requirements is commonly based on average figures, which are acknowledged to be only approximate estimates arrived at by interpolation from the results of actual feeding or digestion trials on other forages or mixed rations.

The use of these average values, however reliable they may be as averages, is of very doubtful worth for determination of the forage consumption of individual grazing animals, because of variations in the efficiency of the animals and in the value of the forages. It is also evident that this method is of no value for precise analytical determination either of rate of consumption or of efficiency of utilization, because the effects of these two factors are combined in producing gain in live weight, which is the only measurement taken under this procedure.

METHOD AND EQUIPMENT USED

Method of Calculating Forage Consumption

The method used for determining the forage consumption of the steers in the twenty-seven experiments reported herein was developed by the senior author, with the aid of his advisers, and was first used in connection with studies reported in "A Method for Accurately Determining the Forage Consumption of a Grazing Steer,"[19*] a master's thesis at the University of Illinois. The method proved so satisfactory in connection with that study, limited tho the study was, that it was employed in this present investigation with practically no modifications. The further use of it here has not suggested the need for changes either in principle or in technique.

The method is based on the assumption that, under uniform conditions and for a reasonable length of time, the percentages of dry matter consumed that will be digested[a] and defecated[b] by a given steer will be almost constant provided the source of the dry matter consumed is roughage of uniform species, stage of maturity, and chemical composition. If therefore the consumption-defecation ratio for a given steer could be determined, his dry-matter intake could be calculated from data on dry matter defecated. Calculation of these ratios for the various steers, followed by analyses to determine the amount of dry matter defecated by steers freely grazing, constituted the general line of attack in this investigation.

Calculation of Consumption-Defecation Ratios.—The procedure fell naturally into two divisions. The object of the first part of each experiment was to determine, for each steer and for each forage tested,

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[a]Apparent digestibility. See footnote b, below.

[b]It is realized that a small fraction of the dry matter defecated is not of feed origin. The results of numerous digestion experiments indicate that the presence of this small fraction does not appreciably affect the constancy of the relationship between dry matter consumed and dry matter defecated under the stated conditions.

the relationship between the total dry matter consumed and the total dry matter defecated.

This part of each experiment consisted of an eight-day "digestion period" preceded by a five-day preliminary period. The steers were placed in specially constructed stalls, the floors of which sloped to the rear and were covered with rubber-covered cotton pads. High-sided mangers were used, and consequently very little of the forage was scattered on the floor.

During the summers of 1932, 1933, 1934, and the first half of the 1935 season, fresh forage from the pasture to be tested experimentally was cut twice daily and fed to the steers during the entire thirteen days at a fixed rate found to be approximately the highest at which no orts would be left.

For the last four experiments in 1935 an electric quick-drier was available,[a] by means of which the percent of dry matter present in the fresh forage could be determined in less than two hours. The forage was cut each morning, and the morning and night feeds were weighed out in such quantities as the dry-matter analysis showed to be required for furnishing the predetermined amounts of dry matter.

Thruout the experiments duplicate dry-matter samples of each feed were taken during the eight-day digestion periods. Orts, if present, were collected once daily, and were weighed and sampled to determine their dry-matter content. Each steer, during this period, was equipped with the harness and feces sack that are described on pages 453 to 458. This equipment collected, without loss, the excrement of the animals. The sack was changed once daily during this period, was weighed, and a representative sample of its contents was analyzed for dry matter. The amount of dry matter defecated during the period the sack was in place was calculated by multiplying the net weight of the collection by the percentage of dry matter found in the sample.

The data thus collected during the digestion period gave the total consumption and the total defecation of dry matter. The dry matter defecated was then expressed as a percentage of the total dry matter consumed. This calculation was made for each steer for every forage that was tested.

Calculation of Forage Consumption under Grazing Conditions.— The object of the second part of each experiment was to determine the average daily dry-matter defecations of each steer while grazing under

[a]This drier was designed and constructed by R. H. Reed, First Assistant in Agricultural Engineering, in cooperation with the junior author of the present bulletin.

as nearly normal conditions as it was possible to maintain with the experimental procedure, and from this data to calculate the amount of dry-matter consumption. This part of the experiment followed the first part, the digestion period, with only a five-day period intervening. Immediately after the close of the digestion period the steers were turned into the field to be tested and were given five days to become accustomed to their surroundings and presumably to reach and maintain a fairly normal and uniform rate of forage consumption and dry-matter defecation before new data were collected.

At the close of this five-day preliminary period the steers were equipped with harness and feces sack, and fecal collections were made over an eight-day period. During this "consumption period" the sacks were changed twice daily so that the animal would not be unduly burdened, also so that no feces would be lost. A representative sample of the contents of each sack was obtained immediately after weighing and was placed in an air-tight can for transportation to the laboratory where the percentage of dry matter was determined and the dry matter contained in each collection was calculated.

The total dry-matter defecation for each steer was determined for the eight days of the consumption period. The forage consumption of a steer during this eight-day period was thereupon calculated by dividing the total dry matter defecated by the ratio between dry-matter defecation and dry-matter consumption which had already been determined in the first part, or digestion period, of the experiment. For example, if the average daily dry-matter defecation of a steer during the consumption period was 4.5 pounds a day, and if in the digestion period he was found to have defecated an average of 30 percent of the dry matter consumed, the average amount of dry matter that he consumed daily during the eight-day consumption period was 15 pounds (4.5 pounds $\div$ .30 $=$ 15 pounds).

Single-day weights of the steers were taken at the beginning of the preliminary grazing period and at the end of the collection period of each experiment. The steers had to be led back to the barn for each weighing. Since the fill and the distance to the scales varied greatly with each set of experiments, the data on gains and losses are probably not significant. For the purpose of calculating the net energy maintenance requirements averages of the initial and final weights of the steers were used.

That any great departure from the normal either of the steer himself or of the grazing conditions might influence the accuracy of the results secured was realized fully. For this reason great care was exercised to provide as nearly normal conditions as possible for the steer during the consumption period of the experiments. Time and care were used to tame the steers so that the necessary handling could be done without unduly exciting them. Shade, water, salt, and companion experimental steers also were provided.

Careful observation by the investigators during four seasons of work with this method indicated that the use of these precautions resulted in as nearly normal grazing conditions as it is possible to maintain under the experimental routine followed.

Another precaution which was taken to increase the relative accuracy was the use of five-day preliminary periods preceding the digestion periods. The dry-matter consumption during these preliminary periods was held at an almost constant level. The dry-matter defecations consequently leveled off so that during the collection periods the dry matter defecated bore a relatively fixed relationship to the dry matter consumed.

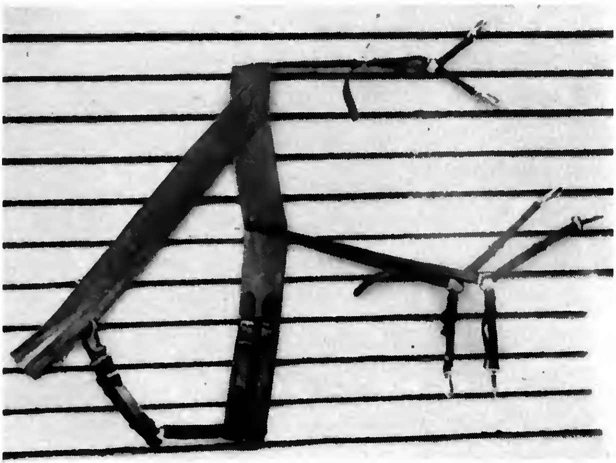

FIG. 2.—ADJUSTABLE HARNESS FOR HOLDING FECES SACK

Description of the Equipment

The equipment used has been modified during the course of these studies until it appears to be highly effective, easily adjusted to the animal, strong enough to stand up under a high overload, and simple enough for use in field experiments. It consists of two parts, the harness and the feces sack.[a] .

[a]A complete description of this equipment with drawings and measurements is included in an unpublished master's thesis[19]* by the senior author of the present bulletin.

No attempt has been made to adapt this equipment for pasture research with females, nor with sheep, hogs, or horses, tho such adaptations appear to be possible.

Harness.—The harness (Fig. 2) was composed of:

1. An easily adjustable girth strap made from 4-inch webbing.

2. A similar strap one end of which was sewed to the girth strap near one side of its uppermost point. This strap extended downward and forward across the animal's shoulders, under both shoulder points, and upward around the other side until it reached a point on the girth corresponding to the position of its other end.

3. A back strap made from ⅞-inch leather, one end of which was sewed to the uppermost part of the girth. This strap extended to a point over the middle of the animal's loin, where it was spliced into a ring. Two shorter straps led from this ring to fasten to the sack at each side of the tailhead. The back strap had a take-up buckle.

4. Two side straps sewed to the girth, each extending rearward and downward to a ring just in front of the rear flank. Two other straps led from this ring, one going upward and fastening to the sack at a point just under the animal's hip bone, and the other downward and fastening to one side of the bib. All these straps were adjustable.

5. A "Y"-shaped strap, two branches of which were attached to the breast strap just under the shoulder points. The third branch extended rearward and was attached to the underside of the girth strap. This strap also was adjustable.

FIG. 3.—TWO SIZES OF FECES SACK AND BIB

Feces Sack.—The sack (Fig. 3), which was an adaptation of the feces duct used by investigators at several nutrition laboratories, was made of heavyweight waterproofed duck. The seams were all double-sewed and taped. The bottom was circular and of double thickness. All edges and points of strain were bound with tape and reinforced with webbing.

The upper portion of this sack fitted snugly to the underside of the animal's tail and extended forward over the animal's rump and upper rounds. A bib extended forward between the animal's legs to direct

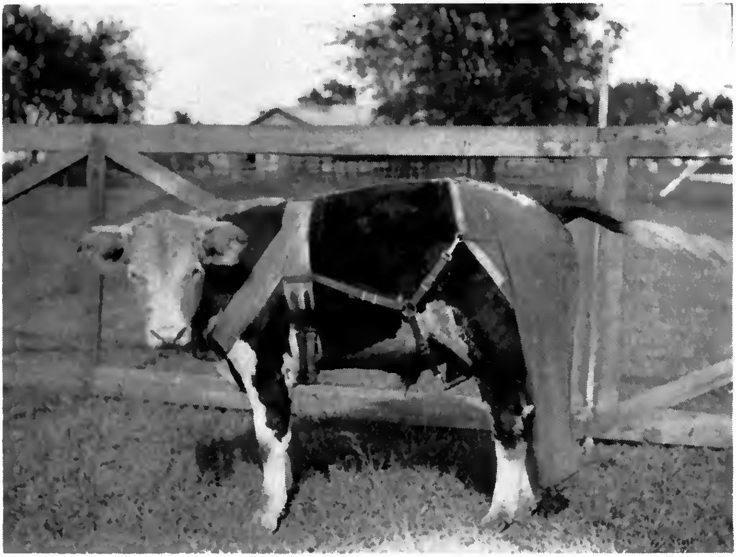

FIG. 4.—HARNESS AND FECES SACK ADJUSTED TO STEER WEIGHING ABOUT 535 POUNDS (STEER B, PUREBRED HEREFORD)

any stray feces backward into the cylindrical part of the sack which extended downward from the animal's hocks to within a few inches of the ground. Patience and skill in design are necessary in fitting equipment to individual steers (Figs. 4-7).

Electric Quick-Drier.—A third piece of equipment, which was added at the middle of the 1935 season, was an electric quick-drier (Fig. 8)[36*] that maintained a temperature of 95° C. with forced ventilation, and removed from the forage samples practically all of the moisture in one and one-half hours. The exact weight of green forage required to furnish a constant and predetermined amount of dry substance to each steer daily during the preliminary and digestion periods

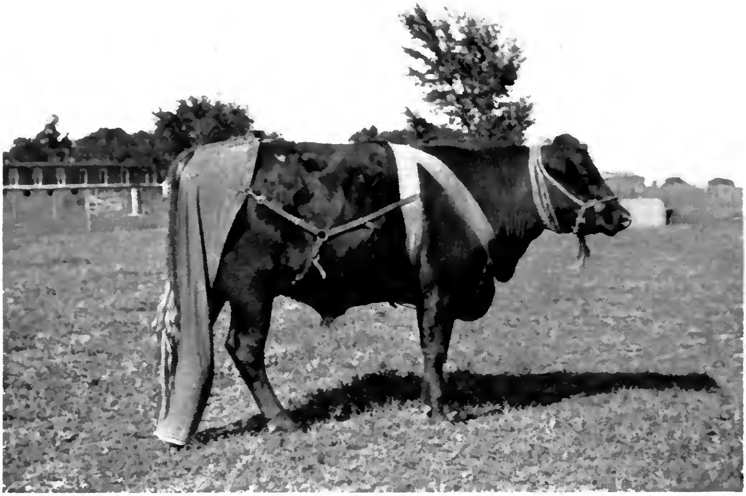

FIG. 5.—HARNESS AND FECES SACK ON STEER WEIGHING ABOUT 950 POUNDS (STEER A, GRADE SHORTHORN)

The feces sack is about 3 inches too long for this animal.

FIG. 6.—HARNESS AND FECES SACK ADJUSTED TO STEER WEIGHING ABOUT 600 POUNDS (STEER C, GRADE SHORTHORN)

FIG. 7.—STEER E, (GRADE SHORTHORN) GRAZING WITH HARNESS AND FECES SACK IN POSITION

The harness and feces sack offer little or no interference with grazing.

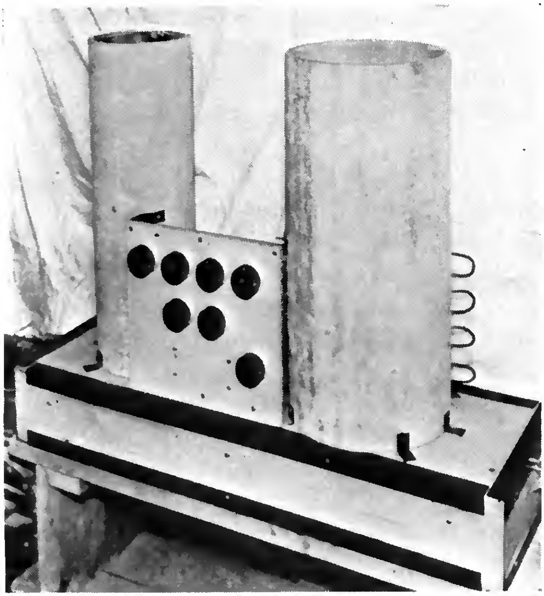

FIG. 8.—ELECTRIC QUICK-DRIER USED FOR DRYING FORAGE SAMPLES IN 1½ HOURS WITH FORCED VENTILATION AT CONSTANT TEMPERATURE

of the experiments could thus be determined before feeding. To be able to regulate so strictly the dry-matter intake during these periods was of course valuable in establishing accurate consumption-digestion ratios.

Mowing Equipment.—In Experiment 1A, the Kentucky bluegrass needed for the digestion period of the experiment was harvested twice daily with a lawnmower equipped with a grass catcher. In experiments 2B thru 7D the clover and alfalfa used in the digestion periods were cut with a hand scythe.

Before the start of the 1934 season, a one-horse mower having a four-foot cutter bar was equipped with a galvanized pan bolted to the rear edge of the cutter bar and extending backward about two and one-half feet. From 30 to 40 pounds of forage could be cut before it was necessary to unload the pan. This specially-equipped mower not only saved time and labor, but also kept the forage clean and permitted the operator to remove easily any large weeds.

ANIMALS USED, FORAGES TESTED, AND EXPERIMENTAL CONDITIONS PREVAILING

Experimental Animals

Twelve steers in all were used in the twenty-seven experiments: Steers A and B in 1932, Steers C and D in 1933, Steers E, F, G, and H in 1934, and Steers I, J, K, and L in 1935. The letter designating the steer is used with the number of the experiment to facilitate indentification.

In order to secure data on any effect that the size of the grazing animal might have on forage consumption, steers of different ages were used, including feeder calves, yearlings, and two-year-olds. The steers chosen ranged in weight from about 350 pounds to nearly 1,000 pounds. While it was realized that the results might have been more significant from a statistical standpoint if steers of uniform weights had been used, the value of obtaining results on steers varying greatly in weight probably more than offset this disadvantage.

All the steers were tested and found to be free from tuberculosis. Only healthy steers in fair to good feeder flesh were selected (Table 1). All the steers were accustomed to a ration composed solely of pasture forage. In fact, but few of them had been fed any appreciable amounts of grain.

All of the animals with the exception of Steer "B" were used in two or more experiments. Consequently the different rates of con-

TABLE 1.—DESCRIPTION OF STEERS USED IN GRAZING EXPERIMENTS

Steer	Breed	Origin	Approximate weight for season	Beef conformation and quality	Indication of feeding capacity	Condition on feeder basis	Temperament	Experiments where used
			lb.					
A	Shorthorn	Native	950	Excellent	Excellent	Good	Medium	1, 3
B	Hereford	University of Illinois	535	Excellent	Excellent	Fleshy	Excellent	2
C	Shorthorn	Native	600	Excellent	Good	Fleshy	Excellent	4, 6
D	Shorthorn	Native	750	Medium to good	Medium to good	Medium	Medium	5, 7
E	Shorthorn	Native	375	Good	Good	Thin to medium	Excellent	8, 12, 16
F	Hereford	Western	600	Fair to medium	Medium	Thin	Medium	9, 13, 17
G	Shorthorn	Native	850	Medium	Good	Good	Good	10, 14, 18
H	Shorthorn	Native	950	Good	Excellent	Medium	Excellent	11, 15, 19
I	Shorthorn	Native	440	Good	Good	Good	Excellent	20, 24
J	Shorthorn	Western	552	Good	Good	Good	Good	21, 25
K	Shorthorn	Native	825	Good	Good	Fleshy	Excellent	22, 26
L	Shorthorn	Native	780	Medium	Medium	Good	Good	23, 27

sumption of a given steer while grazing on several forages may be compared directly.

Forages Tested

Six forages—three grasses and three legumes—in various stages of maturity were tested in these experiments (Table 2).

In Experiment 1 the forage consisted almost entirely of Kentucky bluegrass (*Poa pratensis*). The pasture, located on the University beef cattle farm at Urbana, had been in bluegrass for a number of years, and was apparently in good fertility and not seriously lacking in any necessary mineral or organic elements. During the digestion period this bluegrass contained an average of 40.7 percent dry matter. At the start of the consumption period during the last week of July, it was beginning to head, and the stage of maturity is described as "one-half headed."[a]

The forage used in Experiment 2 was a mixture containing mostly red clover (*Trifolium pratense*) and alsike clover (*Trifolium hybridum*) with a small percentage of grasses and weeds. This pasture was located on the University sheep farm at Urbana on an apparently very fertile field. The forage cut for the digestion period contained on the average 30 percent of dry matter; and the stage of maturity during the consumption period may best be described as one-quarter bloom. This forage was grazed during the middle of August.

A pure stand of North Dakota No. 12 alfalfa (*Medicago sativa*), second growth, was tested in Experiment 3. This pasture also was located on the sheep farm, and was apparently in a high state of fertility. During the digestion period the forage cut contained on the average 27.3 percent of dry matter; and during the consumption period, which was run during the middle of September, the stage of maturity was three-quarter bloom.

The first growth alfalfa used in Experiments 4 and 5 was grown during the following year on the same field as that for Experiment 3. The average stage of maturity during the consumption periods, run for both experiments during the first week of July, may best be described as three-quarter bloom. The average dry matter content of the forage cut for the digestion trials was 26 percent in Experiment 4 and 25.8 percent in Experiment 5. Separate dry-matter samples were taken for Experiments 4 and 5 altho the same forage was used for both. The close agreement between the average dry-matter figures indicates that the sampling was accurate.

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[a]"Stage of maturity" in all tables and discussions refers to the stage at time of grazing.

TABLE 2.—DESCRIPTION OF FORAGES TESTED

Experiments	Forage tested	Species	Variety	Stage of maturity[a]	Percent of dry matter
1	Kentucky bluegrass	*Poa pratensis*	Common	½ headed	40.7
2	Red clover and alsike clover	*Trifolium pratense* *Trifolium hybridum*	Common Common	¼ bloom	30.0
3	Alfalfa	*Medicago sativa*	North Dakota 12	⅛ bloom	27.3
4, 5	Alfalfa	*Medicago sativa*	North Dakota 12	¾ bloom	25.9
6, 7	Alfalfa	*Medicago sativa*	North Dakota 12	Full bloom	29.6
8-11	Kentucky bluegrass	*Poa pratensis*	Common	5 weeks	31.2
12-15	Red clover	*Trifolium pratense*	Common	¾ blossoms brown	32.9
16-19	Red clover	*Trifolium pratense*	Common	¼ bloom	25.6
20-23	Reed canary grass	*Phalaris arundinacea*	Common	6 to 10 inches	21.6
24-27	Bromegrass	*Bromus inermis*	Smooth	4 to 8 inches[b]	28.3

[a]Stage of maturity at time of grazing.
[b]Late fall growth with some older material mixed in.

Alfalfa grown on the same field as that of the two preceding experiments also was used in Experiments 6 and 7. This alfalfa, second growth, contained 29.4 percent of dry matter in Experiment 6 and 29.7 percent in Experiment 7. Here again the average of the duplicate sampling and analysis agreed very closely. The stage of maturity during the consumption period, during the second week in August, was approximately full bloom.

The forage tested in Experiments 8, 9, 10 and 11 was Kentucky bluegrass (*Poa pratensis*) on an old pasture located just north of the sheep barn at the University farm. The pasture was high in fertility and had been grazed for many years by beef cattle. The forage, as cut for the digestion periods, averaged 31.2 percent of dry matter. The grazing period was held during the latter part of May and the first three days of June. The bluegrass at this time was about a five weeks' growth. On a dry-matter basis it contained 18.39 percent of crude protein.

Common or medium red clover (*Trifolium pratense*), first growth, was the forage used in Experiments 12, 13, 14 and 15. This field of two year old clover was located on the Agronomy farm and was made available for these experiments by the Department of Agronomy. The forage as cut for the digestion periods contained on the average 32.9 percent of dry matter. The average stage of maturity during the consumption period, the third week of June, is indicated by the fact that about three quarters of the blossoms had turned brown. Because of the hot and dry weather this clover had matured much more rapidly than is usually the case. On a dry-matter basis, this forage contained 15.80 percent of crude protein.

Red clover also was used in Experiments 16, 17, 18 and 19, and was the second growth on the same field used in the preceding four experiments. The average dry-matter content of the forage as cut for the digestion periods was 25.6 percent. The clover was just coming into bloom during the consumption period and its average stage of maturity during that period may best be described as one-quarter bloom. Grazing was done during the latter part of July and the first two days of August. The old growth had been mowed and removed four weeks earlier in preparation for this test. Crude protein content of the clover on a dry matter basis, was 19.07 percent.

Reed canary grass (*Phalaris arundinacea*) was used in Experiments 20, 21, 22 and 23. This grass was from six to ten inches high when grazed during the latter part of August, and was relatively tender and in very active growth. The field, located on the sheep farm at the University farms, was in a reasonably high state of fertility. The forage contained an average of 21.6 percent of dry matter. Chemical analysis and the apparent digestibility of this forage are shown in Table 3.

Bromegrass (*Bromus inermis*) was used in Experiments 24, 25, 26 and 27, and was from 4 to 8 inches high. Grazing was done during the middle of October after the grass had practically ceased active growth for the season. The field was moderately high in fertility. Some older grass than the 4- to 8-inch growth was contained in the forage. The dry-matter content averaged 28.3 percent. Chemical analysis and apparent digestibility are shown in Table 3.

Conditions Prevailing During the Experiments

Grazing Conditions.—It was realized from the start that the results obtained would not possess their fullest value unless every possible precaution were taken to insure as nearly normal grazing conditions as possible under the experimental routine. Consequently, in all experiments except 2A, abundant pasturage, shade, water, salt, and companion animals were provided at all times for the experimental steers.

In Experiment 2A, the main objective was to compare the results obtained thru the use of the old clipping method and the new method when both were run simultaneously. It was therefore necessary that the steer be confined within a pen 4 square rods in area. Altho this pen was moved daily to a new location and fresh water was available at all times, shade, companion animals, and the freedom to roam were lacking. For this reason, the data collected have been used only in a comparison of the results obtained with the two methods and have not been compared with results obtained in the other experiments where the grazing conditions were much more nearly normal.

During the running of Experiment 1A the steer's tail became quite swollen and sore because of friction with the sack produced by continual switching of the tail and also because of congestion or poor circulation at the root of the tail. Swelling and soreness, tho less than in 1A, was noticed in Experiments 3A, 5D, 6C and 7D. No soreness developed in Experiments 2B and 4C. Cotton pads, gall lotion, and glycerite of tannic acid were used in an attempt to reduce the irritation, but were of little value. Starting with Experiment 8E and continuing thruout the succeeding experiments, a commercial preparation called "Phenocamph Compound" was dusted on all tails that showed any signs of irritation or swelling, and proved to be very effective in reducing irritation and curing any soreness which developed.

TABLE 3.—REED CANARY GRASS AND BROMEGRASS TESTED IN EXPERIMENTS: COMPOSITION, APPARENT DIGESTIBILITY, AND DIGESTIBLE NUTRIENTS

Item	Reed canary grass[a]			Bromegrass[b]		
	Composition	Apparent digestibility[c]	Digestible nutrients[c]	Composition	Apparent digestibility[d]	Digestible nutrients[d]
Dry-matter, percentage	100	61.39	61.39	100	51.79	51.79
Crude protein, percentage	27.90	85.07	23.73	24.06	78.51	18.89
Crude fiber, percentage	26.19	71.46	18.72	26.78	58.84	15.76
N-free extract, percentage	24.47	46.09	11.28	31.95	40.23	12.85
Ether extract, percentage	7.06	53.26	3.76	6.26	38.95	2.44
Gross energy (calories/pounds)	1 898	63.64[e]	1 208	1 960	52.19[e]	1 023

[a]The reed canary grass was young, relatively tender, and in active growth.
[b]The bromegrass contained some older forage and had nearly completed its active growth for the season.
[c]Average of four digestion experiments, 201 to 23L.
[d]Average of three digestion experiments, 24I, 26K, 27L.
[e]Percent digestibility of gross energy.

Altho the tails apparently never became sore enough to affect the results, chances of infection and serious trouble were always present.

In the majority of the experiments a pen 1 rod square in which the steers might be caught with a minimum of excitement was provided in a corner of each field. This precaution was usually found to be unnecessary because the steers soon became easy to catch.

TABLE 4.—DESCRIPTION OF WEATHER DURING THE CONSUMPTION PERIODS

Experiments	Temperature			Rainfall	
	Mean, daily	Average maximum, daily	Maximum for period	Total during period	Total, preceding week
	°F.	°F.	°F.	*inches*	*inches*
1	77.9	85.8	92	.83	0
2	73.9	81.6	90	.40	.41
3	69.1	79.9	89	1.84	.37
4, 5	82.0	91.2	99	trace	1.09
6, 7	75.9	83.1	91	1.64	1.90
8-11	80.8	93.0	103	1.09	.26
12-15	85.6	94.1	101	1.12	2.55
16-19	79.3	88.8	95	.35	.23
20-23	74.0	82.8	86	trace	1.00
24-27	63.6	74.2	83	.28	.40

Weather.—Temperature and rainfall may exert some influence on the rate of consumption of forage by steers. For that reason, complete weather data for the periods covered by these experiments are summarized in Table 4.

During Experiments 8 through 19 the prevailing temperatures were unusually high, tho they apparently were not sufficiently high to cause any marked discomfort to the steers until the start of the preliminary period for Experiments 16 through 19. The mean daily temperature for this period was 92 degrees. The steers became somewhat overheated before artificial shade was provided, but they quickly returned to normal after shade was installed, and they were thereafter allowed a six-day preliminary period before data were collected. At the start of the collection periods the temperature moderated rapidly, and it is safe to say that the consumption of forage during these four experiments was not appreciably affected by the overheating of the steers before the start of the preliminary periods.

Lack of rain during May of 1934, together with severe dust storms, caused the Kentucky bluegrass forage used in the digestion periods of Experiments 8 through 11 to become very dusty. A light rain at the start of the preliminary period, another on the third day of the preliminary period, together with three more during the collection period served to wash off the grass and apparently restored its palatability.

RESULTS: DRY-MATTER CONSUMPTION OF THE SEVERAL FORAGES

Alfalfa Experiments

Five experiments were run on alfalfa, the first, 3A, during 1932, and the other four, 4C, 5D, 6C and 7D, were completed during the summer of 1933.

The essential results obtained in these five experiments are given in Table 5. It should be remembered that the calculated total dry matter consumed during the eight-day consumption period (column 7) is equal to the total dry matter defecated during the consumption period (column 6) divided by the ratio between dry matter defecated and dry matter consumed (column 5). It should also be noted that experiments 4C and 5D were run concurrently on the same forage. This was likewise the case with Experiments 6C and 7D.

TABLE 5.—ALFALFA EXPERIMENTS: DRY MATTER CONSUMED BY STEERS DURING CONSUMPTION PERIOD

Experiment and steer	Average weight of steer	Stage of maturity of forage[a]	Dry-matter content of forage	Ratio of dry matter defecated to dry matter consumed[b]	Total dry matter defecated	Calculated total dry matter consumed	Calculated average daily dry-matter consumption
	lb.		*perct.*	*perct.*	*lb.*	*lb.*	*lb.*
3A	988	¾ bloom	27.3	46.4	48.70	105.0	13.1
4C	602	¾ bloom	26.0	33.0	27.72	84.0	10.5
5D	758	¾ bloom	25.8	33.5	32.17	96.0	12.0
6C	618	Full bloom	29.4	37.1	30.21	81.4	10.2
7D	775	Full bloom	29.7	34.9	33.40	95.7	12.0

[a]Stage of maturity at time of grazing.
[b]Determined during the digestion period.

Steers C and D each consumed a remarkably uniform average amount of dry matter during this series of experiments. In percent of the dry matter digested, the different steers differed widely. Steer A defecated 46.4 percent of the dry matter he consumed in the form of ¾ bloom alfalfa, whereas steers C and D defecated only 33.25 percent of the dry matter they consumed in comparable forage. This difference can hardly be attributed to the forages tested as the forage used in Experiment 3 was second growth, and that used in Experiments 4 and 5 was first growth alfalfa.

Kentucky Bluegrass Experiments

Five experiments were run on Kentucky bluegrass. Experiment 1A was run in 1932 and Experiments 8E, 9F, 10G and 11H were run in 1934 concurrently on the same field.

The essential results obtained in these five experiments are given in Table 6. The interpretation given for Table 5 applies also to this table.

As would be expected the younger Kentucky bluegrass not only contained less dry matter but was also more completely digested by the steers than was the older bluegrass used in Experiment 1A. The

TABLE 6.—KENTUCKY BLUEGRASS EXPERIMENTS: DRY MATTER CONSUMED BY STEERS DURING CONSUMPTION PERIOD

Experiment and steer	Average weight of steer	Stage of maturity of forage[a]	Dry-matter content of forage	Ratio of dry matter defecated to dry matter consumed[b]	Total dry matter defecated	Calculated total dry matter consumed	Calculated average daily dry-matter consumption
	lb.		*perct.*	*perct.*	*lb.*	*lb.*	*lb.*
1A	938	½ headed	40.7	36.4	75.10	206.3	25.8
8E	364	5 weeks	31.2	30.7	25.52	83.1	10.4
9F	584	5 weeks	31.2	31.4	31.71	101.0	12.6
10G	844	5 weeks	31.2	29.1	33.49	115.1	14.4
11H	940	5 weeks	31.2	26.7	46.43	173.9	21.7

[a]Stage of maturity at time of grazing.
[b]Determined during the digestion period.

large steers used in Experiments 1A and 11H consumed quite large amounts of dry substance daily and, as will be brought out later, consumed the largest percents of their respective maintenance requirements of any steers in the investigation.

Red-Clover Experiments

A total of eight red-clover experiments was run, all during the summer of 1934. Experiments 12E, 13F, 14G and 15H were run on first growth two-year-old red clover that had matured to the stage where three-fourths of its blossoms had become brown. Experiments 16E, 17F, 18G and 19H were all run on second-growth two-year-old red clover in the one-quarter bloom stage of maturity.

The essential results obtained in these eight experiments are given in Table 7. The last line of Table 7 also lists the results obtained in Experiment 2B which was run in 1932 on a mixture of red clover, alsike clover, and some grasses and weeds. It should be remembered that during this experiment the steer was confined daily to a four-square-rod area of forage in order to compare directly the new and the old methods. For this reason, as well as because of the differences in forage, the results of this experiment should not be compared with the results of the eight preceding red-clover experiments.

The interpretation given for Table 5 also applies to this table.

The larger content of dry matter in the more mature clover was digested almost as completely as that of the quarter bloom clover. Whether the usual lowered digestibility of dry matter due to advanced maturity is less marked with this forage than with others requires further elucidation.

TABLE 7.—RED CLOVER EXPERIMENTS: DRY MATTER CONSUMED BY STEERS DURING CONSUMPTION PERIOD

Experiment and steer	Average weight of steer	Stage of maturity of forage[a]	Dry-matter content of forage	Ratio of dry matter defecated to dry matter consumed[b]	Total dry matter defecated	Calculated total dry matter consumed	Calculated average daily dry-matter consumption
	lb.		*perct.*	*perct.*	*lb.*	*lb.*	*lb.*
12E..........	362	¾ blossoms brown	32.9	36.8	36.26	98.5	12.3
13F..........	582	¾ blossoms brown	32.9	35.3	55.59	157.5	19.7
14G..........	834	¾ blossoms brown	32.9	35.2	54.86	155.9	19.5
15H..........	942	¾ blossoms brown	32.9	30.7	61.48	200.3	25.0
16E..........	394	¼ bloom	25.6	36.7	40.92	111.5	13.9
17F..........	622	¼ bloom	25.6	36.8	49.19	133.7	16.7
18G..........	862	¼ bloom	25.6	36.4	51.07	140.3	17.5
19H..........	963	¼ bloom	25.6	34.6	60.81	175.8	22.0
2B[c]..........	535	¼ bloom	30.0	36.4	35.74	98.2	12.3

[a]Stage of maturity at time of grazing.
[b]Determined during the digestion period.
[c]The forage tested in this experiment was a mixture of red clover and alsike clover, with some grasses and weeds. These results should not be compared with those of the eight preceding experiments.

Reed-Canary-Grass Experiments

Four experiments were completed on reed canary grass during the 1935 season. The essential data concerning these experiments are given in Table 8. The explanation given for Table 5 applies also to this table.

All four steers exhibited an extreme dislike for the reed canary grass when it was first offered to them in the digestion stalls. After three or four days of semistarvation they were beginning to consume fair amounts but obviously did not relish it. When first turned into the field for the consumption period, they greedily devoured a few small patches of smart weed before resuming their diet of reed canary grass.

Despite this marked preference for other forage all steers except I consumed quite large amounts of the reed canary grass. This instance indicates that "palatability" as usually measured does not give a true indication of the levels of sustained consumption that will be encouraged by the different forages.

That this forage was in a tender and succulent stage is indicated by its relatively low content of dry substance. The extremely harsh leaf edges of mature reed canary grass might logically and materially reduce its consumption from the level sustained in these experiments.

TABLE 8.—REED CANARY GRASS EXPERIMENTS: DRY MATTER CONSUMED BY STEERS DURING CONSUMPTION PERIOD

Experiment and steer	Average weight of steer	Stage of maturity of forage[a]	Dry-matter content of forage	Ratio of dry matter defecated to dry matter consumed[b]	Total dry matter defecated	Calculated total dry matter consumed[c]	Calculated average daily dry-matter consumption[c]
	lb.	*inches*	*perct.*	*perct.*	*lb.*	*lb.*	*lb.*
20I.	410	6 to 10	21.6	40.7	24.04	59.05	7.4
21J.	505	6 to 10	21.6	37.1	43.28	118.64	14.8
22K.	800	6 to 10	21.6	36.9	45.82	125.05	15.6
23L.	745	6 to 10	21.6	39.7	49.16	123.70	15.0

[a]Stages of maturity at time of grazing.
[b]Determined during the digestion period.
[c]Corrected for changes in ash content of digestion-period and consumption-period feces (see page 488).

Bromegrass Experiments

A total of four experiments were completed on bromegrass during the 1935 season. The essential data concerning these experiments are given in Table 9. The explanation given for Table 5 applies also to this table.

The bromegrass used in these experiments was from a field that had been mowed earlier in the season and was mainly new growth,

TABLE 9.—BROMEGRASS EXPERIMENTS: DRY MATTER CONSUMED BY STEERS DURING CONSUMPTION PERIOD

Experiment and steer	Average weight of steer	Stage of maturity of forage[a]	Dry-matter content of forage	Ratio of dry matter defecated to dry matter consumed[b]	Total dry matter defecated	Calculated total dry matter consumed[c]	Calculated average daily dry-matter consumption[c]
	lb.	*inches*	*perct.*	*perct.*	*lb.*	*lb.*	*lb.*
24I.	470	4 to 8	28.3	49.2	33.97	67.72	8.5
25J.	600	4 to 8	28.3	48.2[d]	57.02	114.52	14.3
26K.	850	4 to 8	28.3	45.8	56.09	118.95	14.9
27L.	815	4 to 8	28.3	49.6	52.23	100.28	12.5

[a]This bromegrass, which contained some older growth, was tested in October after it had nearly ceased its active growth for the season. Stage of maturity is at time of grazing.
[b]Determined during the digestion period.
[c]Corrected for changes in ash content of digestion-period and consumption-period feces (see page 488).
[d]No digestion trial was run on this steer (see footnote, page 470). An average of the coefficients obtained with the other three steers was used.

four to eight inches tall. However, this fall growth was produced much more slowly than spring growth and the percentage digested was lower than those reported for spring growth. Consequently, the results reported in Table 9 should not be considered as representative of the value of bromegrass produced earlier in the season. These results do, however, indicate that bromegrass may lose some of its palatability as the season progresses. This indication has also been found in steer-feeding trials conducted at this station. For the first sixty days of the grazing season, bromegrass has produced more rapid gains than bluegrass, alfalfa, or sweet clover.

As was true when the steers were grazing on reed canary grass, Steer I consumed less than would appear to be his share, and steer J[a] consumed relatively more than his share. This indicates marked variation in the rates of forage consumption by different steers.

AMOUNT OF FORAGE CONSUMED AND AMOUNT NEEDED TO FURNISH THE NET ENERGY MAINTENANCE REQUIREMENT, AS A MEANS OF COMPARING LEVELS OF FORAGE INTAKE

In any study of the effect of different species and maturity of forage, or of size of steers, on forage consumption, some common basis of comparison must be established. Obviously the total quantity of forage consumed is no accurate criterion in itself, for the consumption and requirements of steers of different weights vary greatly. But neither is the ratio of total consumption to total weight of steer an altogether trustworthy basis. In the present experiments a careful analysis of the data failed to disclose any consistent relationships between the amount of forage consumed, on either a green- or a dry-weight basis, and the weight of the steers.

In this study the level of feed consumption is expressed as a percentage of the amount of forage needed to supply the steers' maintenance requirement of net energy. While some valid objections may be raised against this procedure, it appears to offer the most accurate, clear and uniform method of comparing the data obtained on steers of various weights.

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[a]No digestion trial was completed in Experiment 25J. This steer, for some unknown reason, became frightened one night while confined in his digestion stall, and bruised himself to such an extent that it was considered necessary to remove him from the stall and allow him to rest for a week or so. By the time he was in good shape again, the other three steers had completed their digestion periods. All four were thereupon turned out in the bromegrass pasture for the preliminary period.

Determining the Maintenance Requirement of a Steer

In calculating the standard metabolism of the steers in these experiments use was made of the coefficient for standard metabolism, 1,897 Calories per square meter of body surface, arrived at by Mitchell *et al*[31*] in thirteen determinations of the standard metabolism of beef steers ranging in weight from approximately 800 to 1,400 pounds. This figure for standard metabolism appears to be as reliable as any yet published. Surface area was computed by the Brody formula

$$A = .13\,W^{.56}$$

in which A is the surface area in square meters and W is the weight in kilograms.

Standard metabolism so calculated takes into account the energy expenditures of the animal while standing twelve hours and lying down twelve hours, and also that used in getting up and lying down. But no allowance is made for any horizontal locomotion, and consequently the energy so expended was added to the standard metabolism to obtain the maintenance requirement of net energy for each steer, as given in Table 10.

The energy requirement for horizontal locomotion of cattle was found in a Missouri study[22*] to be 33 Calories per 100 pounds of live

TABLE 10.—NET ENERGY MAINTENANCE REQUIREMENTS OF THE STEERS

Experiment and steer	Weight of steer	Surface area of steer	Standard metabolism of steer	Energy of of locomotion	Maintenance requirement of steer
	lb.	*sq. meters*	*Calories*	*Calories*	*Calories*
1A	938	3.86	7 322	310	7 632
2B	535	2.81	5 331	177	5 508
3A	988	3.97	7 531	326	7 857
4C	602	3.01	5 710	199	5 909
5D	758	3.42	6 488	250	6 738
6C	618	3.05	5 786	204	5 990
7D	775	3.46	6 564	256	6 820
8E	364	2.27	4 306	120	4 426
9F	584	2.96	5 615	193	5 808
10G	844	3.63	6 886	279	7 165
11H	940	3.86	7 322	310	7 632
12E	362	2.26	4 287	119	4 406
13F	582	2.95	5 596	192	5 788
14G	834	3.61	6 848	275	7 123
15H	942	3.86	7 322	311	7 633
16E	394	2.37	4 496	130	4 626
17F	622	3.06	5 805	205	6 010
18G	862	3.68	6 981	284	7 265
19H	963	3.91	7 417	318	7 735
20I	410	2.43	4 610	135	4 745
21J	505	2.73	5 179	167	5 346
22K	800	3.53	6 696	264	6 960
23L	745	3.39	6 431	246	6 677
24I	470	2.62	4 970	155	5 125
25J	600	3.00	5 691	198	5 889
26K	850	3.65	6 924	280	7 204
27L	815	3.56	6 753	269	7 022

weight per mile travelled. But no method other than actual observation and measurement has yet been devised for determining the exact distance that steers travel while grazing. Published studies of the activity of grazing cattle were thoroly reviewed for data on distances travelled; but inasmuch as most of these studies dealt with cattle on range, the results were hardly applicable to the present study.

The general movements of the steers during the day were therefore observed in order to estimate the distance travelled. A distance of one mile a day was decided to be a safe average figure to use. Because the energy used in this manner, at the rate of 33 Calories per 100 pounds of live weight per mile, is so small a fraction of the total energy requirements, it is believed that the very small error that is probable from the use of the average figure would be insignificant when compared with the total net energy maintenance requirement.

Possibilities of Error in Calculating Net Energy Values of Forages

Tho there are no doubt several possibilities of error in the following procedure for calculating the net energy values of the different forages, the errors have probably been reduced as much as possible without actual determination of the net energy values. Forbes's base figure for alfalfa, Woodman's relative starch equivalents and the relationship between digestible and net energy as found by Forbes *et al* appear to be reasonably reliable. The other data used were selected for their apparent reliability and direct bearing on the subject.

The estimated net energy values for maintenance, of the forages used in this investigation, are given in Table 11. It must be remembered that all the net energy values given are for maintenance and not for gain or milk production. It should also be remembered that these

TABLE 11.—CALCULATED NET ENERGY FOR MAINTENANCE PROVIDED BY THE FORAGES USED IN THE TWENTY-SEVEN EXPERIMENTS

Forage	Stage of maturity of forage[a]	Experiments and steers	Net energy per pound of dry matter
			Calories
Alfalfa	¾ bloom	3A, 4C, 5D	760
Alfalfa	Full bloom	6C, 7D	714
Kentucky bluegrass	5 weeks old	8E thru 11H	1 088
Kentucky bluegrass	½ headed	1A	980
Red clover	¾ blossoms brown	12E thru 15H	735
Red clover	¼ bloom	2B, 16E thru 19H	860
Reed canary grass	6 to 10 inches	20I thru 23L	825
Bromegrass	4 to 8 inches[b]	24I thru 27L	699

[a]Stage of maturity at time of grazing.
[b]Late fall growth that contained some older forage.

net energy values deal merely with a part of the *interpretation* of the data and not with the original data themselves.

In determining the net energy values of feeds the energy expense connected with consumption, digestion, metabolism, excretion, and defecation is subtracted from the metabolizable energy. The net energy content of the forage consumed may thus be related directly to the net energy requirements for maintenance of the steers.

Net Energy Value May Vary with Level of Intake.—The net energy values of some feeds, it is recognized, vary with the level of feed intake. The utilization of the energy of feeds fed above the maintenance level was found by Forbes *et al*[17*] to be only about 76 percent of the relative utilization of the energy of the same feeds when fed at or below the maintenance level. Further work by the same group[16*] indicated that the percentage of utilization of metabolizable energy at various levels of feeding is different for roughage than for concentrates, and that this percentage of utilization varies at the different levels of feed intake.

The reasons for these variations were suggested by Mitchell *et al,*[31*] who concluded that the decrease in total utilization of feed by steers "seems to be due in part to a more or less continuous decrease in digestibility, but also to a very slight specific dynamic effect of feed at very low levels of feeding." Level of feed intake has been found to have relatively little effect on the digestibility of roughages when fed alone.[52*] It seems logical to assume, therefore, that the percentage of utilization of roughages varies with level of intake less than does the percentage of utilization of concentrates or of mixed rations.

The method of expressing variable utilization of feeds has been the subject of certain differences of opinion. According to Forbes *et al,*[16*] the question is fundamentally "whether the essential difference in the economy of utilization of food energy for maintenance and milk production, as compared with body increase, shall be expressed in terms of different net-energy values, or whether, for the sake of convenience, one net-energy value is to be used, and the difference in economy of utilization of food energy is to be expressed in the feeding standard."

Uncorrected Net Energy Values Used Here.—Somewhat the same question arose in the interpretation of the present results, the question whether a correction of the net energy values of the forages should be attempted on the basis of the scant evidence available, or whether, for the purpose of measuring the level of forage intake, a single net energy value for each forage should be used.

Because this investigation deals primarily with the *rates* of forage intake and not with the *nutritive values* of the forage intakes, no adjustment for level of feed intake on the net energy value of the different forages was made. In the making of this decision the following factors have been considered: (1) Correction of the net energy value of a feed, to be accurate, probably should be made on the basis of a sliding scale. (2) Existing data concerning the magnitude of these corrections are inadequate for the development of a sliding scale. (3) Roughages probably require corrections that are different and smaller than those used for concentrates. (4) It has not yet been decided whether one net energy value should be given to each feed and the difference in economy of utilization stated, or whether different net energy values should be given for the different levels of feed intake.

By estimating as accurately as possible the net energy values of the different forages when fed at the maintenance level, using these values to determine the number of pounds of dry forage needed to maintain the energy balance of each steer, and then relating the actual consumption of forage to this maintenance requirement of dry forage, it is felt that a clearer picture of the relative forage consumptions can be obtained. Results evaluated by this method may perhaps be so interpreted as to exaggerate the actual worth to the steer of the more palatable forages, but on the other hand a correction for the lower net energy value of feed consumed above the maintenance level might lead to a misinterpretation that would minimize the importance (1) of increased palatability as related to carrying capacity of pastures, and (2) of production figures secured from agronomic studies.

Wherever in this bulletin, therefore, the *net energy consumption* or the *percent of net energy maintenance requirement* is referred to, the *uncorrected* net energy values have been used.

Method Used in Calculating Net Energy Values.—No determinations of the net energy values of forages comparable to those dealt with in this bulletin were found in the literature of the subject. Scientific pasture research is such a new field that only a few starch equivalents and net energy values have been determined for pasture forages.

In devising approximate net energy values for the forages used here, reliable basic figures, the best available supplementary information, and known relationships have been used.

Net Energy Values of Forages

Alfalfa.—In four carefully executed determinations of net energy values, Forbes *et al*,[16*] found that alfalfa hay when fed at maintenance levels to steers had an average net energy value of 655 Calories per pound of dry matter. This average has been chosen as a base from which to work in the present study because of the following reasons: (1) the steers were fed at maintenance levels; (2) the investigators made use of the latest available knowledge, which had shown previous determinations to be in error; (3) the figure arrived at was an average of four carefully controlled and closely agreeing experiments; and (4) these determinations were made on alfalfa, which is one of the forages dealt with in this bulletin.

Inasmuch as the net energy value, 655 Calories per pound of dry matter, was obtained with alfalfa hay, it was necessary to derive by employing existing knowledge a corresponding figure for the green alfalfa forage used in Experiments 3A to 7D inclusive.

Apparently no net energy comparisons have been made on cured and uncured forages, tho a number of feeding trials have been carried out for the purpose of determining the relative digestibility of fresh, artificially dried, and sun-cured hays and grasses. In an experiment with dairy cows[34*] artificially dried grass was shown to be slightly higher in total digestible nutrients per pound of dry matter than the same grass when fresh. Another feeding trial[2*] showed that artificially dried hays apparently had a higher nutritive value than the same hays sun-cured. Still other experiments, however, have found that artificial drying apparently does not greatly affect the digestibility of the nutrients of grasses. Thus, in the light of available information, and in the absence of more specific data, it is assumed that the mere curing of alfalfa does not materially affect its net energy content. Any error on this assumption would doubtless be on the conservative side.

Handling the hay during the hay-making process may, however, affect its net-energy content, for some of the leaves are of course lost in handling. Swanson and Latshaw[47*] have made chemical analyses of alfalfa hay as cut and after baling, and according to their data commercial baled hay has on the average approximately 2 percent fewer Calories of net energy per pound of dry matter than the same hay without any loss of leaves.

The stage of maturity of the hay studied by Forbes is not stated, but its chemical composition, when studied in relation to available experimental evidence, seems to place it about midway between the full-bloom and the seed stage, as those are usually defined. Because the stage of maturity has a decided influence on the starch equivalent and therefore the net energy value of a hay,[57*] it is necessary to make this additional correction of Forbes's value before the probable net energy values of the forages used in this investigation can be arrived at. This correction may be made by comparing starch equivalents.

Altho it is believed that calculated starch equivalent values of such feeds as forages do not accurately measure the net energy content of the feeds, the relationships between the starch equivalents for the same forage in different stages of maturity should be more accurate than the equivalents themselves, when these starch equivalents have been determined by means of digestion trials.

The calculated starch equivalent of alfalfa in bud was found by Woodman *et al*[57*] to be 14 percent larger than that for alfalfa in bloom. A similar decrease in calculated starch equivalent also takes place between the full-bloom and seed stages, and, therefore, the net energy content of the full-bloom alfalfa is probably 14 percent greater than that of alfalfa in the seed stage. The hay used by Forbes has been placed midway between these two stages.

Upon this basis, the net energy content of the full-bloom alfalfa used in Experiments 6C and 7D was 7 percent greater than that of Forbes's hay because of difference in maturity, and 2 percent greater because of the higher percentage of leaves. The probable net energy content of the fresh alfalfa used in Experiments 6C and 7D was thus 109 percent of 655 Calories, or 714 Calories per pound of dry matter when fed at a maintenance level.

By the same reasoning it is logical to add an additional 7 percent to arrive at the probable net energy content of the three-quarter bloom alfalfa used in Experiments 3A, 4C, and 5D. The net energy content of this forage probably was therefore approximately 760 Calories per pound of dry matter.

Red Clover.—Red-clover hay was found by Mitchell *et al*[29*] to be worth about 5 percent more than alfalfa hay for maintaining sheep. And Forbes *et al*[18*] found that for steers the red-clover hay had a net energy content 5.8 percent greater than alfalfa hay. The stage of maturity of the hays used was not stated either by Mitchell or by Forbes, but the chemical analyses that were given show that the alfalfa hays in both cases contained a considerably higher percentage of crude protein than the clover hays. Alfalfa and red clover that are cut at the same stages of maturity have approximately the same crude protein contents on a dry-matter basis, as shown by Willard,[54*] but farmers in the corn belt usually cut red clover for hay at a later stage of maturity than alfalfa. These two facts clearly indicate that the red-clover hays used by Mitchell and Forbes were more mature than their alfalfa hays.

Inasmuch as the net energy content of forages per pound of dry matter decreases as their maturity advances, as already pointed out, page 475, it is logical to conclude that the superiority of red clover over alfalfa in net energy content is greater than the nearly 6 percent found by Forbes and Mitchell. To the red clover is assigned, therefore, a net energy content per pound of dry matter 10 percent greater than that of alfalfa, when both are in the same stage of maturity.

In assigning a net energy content to the red clover used in Experiments 12E to 15H inclusive, the clover was assumed to be in approximately the same stage of maturity as Forbes's alfalfa hay, which was used as a base, with a net energy content of 655 Calories per pound of dry matter. Correction of 2 percent for loss of leaves in the hay, and of 10 percent for the greater net energy value of red clover, gives 735 Calories per pound of dry matter as the net energy content of red clover when three-fourths of the blossoms have turned brown.

The quarter-bloom red clover used in Experiments 16E to 19H had a still higher net energy content. If advancing maturity affects the net energy content of red clover in the same way that Woodman *et al*[57*] found to be true with alfalfa, red clover in bud is about 14 percent higher in net energy per pound of dry matter than red clover in full bloom. The quarter-bloom red clover would therefore have 10.5 percent more net energy per pound of dry matter than full-bloom red clover. Full-bloom alfalfa was assumed to have a net energy content of 714 Calories per pound of dry matter. Adding the 10.5 percent to allow for the earlier stage of maturity, and another 10 percent for the increased value of red clover over alfalfa gives the quarter-bloom red clover a net energy value of about 860 Calories per pound of dry matter.

Kentucky Bluegrass.—Woodman *et al*[56*] found that five-week-old pasture grass had a starch equivalent 52.4 percent greater than that of alfalfa in bloom. The net energy value of this pasture grass used by Woodman is assumed to be equal to the net energy value of the Kentucky bluegrass of the same age used in Experiments 8E to 11H inclusive. This assumption is borne out by the similarity of the chemical composition and digestibility of the grass used by Woodman *et al* and of Kentucky bluegrass as determined by Woodward *et al.*[59*] Thus, if five-week-old Kentucky bluegrass has a net energy value 52.4 percent greater than that of full-bloom alfalfa, which was assumed to be 714 Calories per pound of dry matter, the Kentucky bluegrass contains 1,088 Calories of net energy per pound of dry matter.

The Kentucky bluegrass used in Experiment 1A was considerably more mature than that used in Experiments 8E to 11H. This advance in maturity, it is assumed, would lower the net energy content by 10 percent, or to about 980 Calories per pound of dry matter.

The net energy value of 1,088 Calories per pound of dry matter in five-week-old Kentucky bluegrass is considerably higher than values previously assigned to it. Vermont data[34*] may be used to show that ten-day-old grass had a probable net energy value of more than 1,400 Calories per pound of dry matter when fed to four dairy cows. Another Vermont publication[7*] reports that dried young grass was 96 percent as valuable per pound of dry matter as a dairy grain mixture for body gain and milk production. These facts indicate that the value used for Kentucky bluegrass is not far out of line.

Reed Canary Grass.—Gross-energy determinations, by bomb calorimeter, for feed and feces of the digestion periods of Experiments 20I thru 23L indicated that the reed canary grass used contained on the average 1,208 Calories of digestible energy per pound of dry matter. The percentage of digestible energy of average maintenance rations that is available to the steer as net energy was found by Forbes *et al*[15, 16*] to be approximately 68.29 percent. According to this percentage, the reed canary grass had about 825 Calories of net energy per pound of dry matter. This value bears almost exactly the same relationship to the calculated starch equivalent (calculated from data given in Table 3) of the reed canary grass as the net energy values of the other forages bear to their respective starch equivalents. The net energy value that was assigned is therefore assumed to be approximately correct.

Bromegrass.—Gross energy determinations, by bomb calorimeter, were also made of the feed and feces during the digestion periods for bromegrass Experiments 24I, 26K and 27L. According to these determinations the bromegrass tested contained on the average 1,023 Calories of digestible energy per pound of dry matter. Assuming, as was done with the reed canary grass, that 68.29 percent of this digestible energy was available as net energy, the bromegrass contained 699 Calories of net energy per pound of dry matter. Here again the relationship between calculated starch equivalent and net energy value was practically identical to corresponding relationships for the other forages.

Levels of Intake Best Represented by Comparing Intake With Net Energy Maintenance Requirement

From the net energy values of the different forages (Table 11) and the requirements of net energy for maintenance of the steers (Table 10), the amount of dry forage needed to furnish a maintenance ration of net energy for each steer may be calculated. These requirements may be related to the actual dry-matter intakes of the respective steers. These relationships, expressed in percentage form, are given in Table 12.

It is generally known that young animals usually consume the equivalent of a larger percentage of their weight when on full feed than do the older and heavier animals.[4, 37*] It seems only logical to assume that this would be the case in these experiments.

An analysis of the data by combining the results from steers E, F, G, and H on three different forages shows (Table 19) that the average daily dry-matter consumption of these steers weighing on an average 373, 596, 847, and 948 pounds, respectively, was equal to 3.26, 2.74, 2.03, and 2.41 percent, respectively, of their body weights. A similar analysis (Table 19) of the rates of consumption of steers I, J, K, and L grazing on two forages shows that these steers, averaging 440, 552, 825 and 780 pounds in live weight respectively, consumed

TABLE 12.—RELATIONSHIPS BETWEEN DRY MATTER CONSUMED AND AMOUNT OF DRY FORAGE REQUIRED FOR MAINTENANCE IN THE TWENTY-SEVEN EXPERIMENTS

Experiment and steer	Forage tested	Stage of maturity of forage[a]	Calculated average daily dry-matter consumption	Net energy per pound of dry forage	Net energy maintenance requirement of steer per day	Pounds of dry forage per day for maintenance	Percent of maintenance requirement consumed
			lb.	*Calories*	*Calories*	*lb.*	
1A......	Kentucky bluegrass	½ headed	25.8	980	7 632	7.79	331
2B......	Clover, mixed	¼ bloom	12.3	860	5 508	6.40	192
3A......	Alfalfa	¾ bloom	13.1	760	7 857	10.34	127
4C......	Alfalfa	¾ bloom	10.5	760	5 909	7.78	135
5D......	Alfalfa	¾ bloom	12.0	760	6 738	8.87	135
6C......	Alfalfa	Full bloom	10.2	714	5 990	8.39	122
7D......	Alfalfa	Full bloom	12.0	714	6 820	9.55	126
8E......	Kentucky bluegrass	5 weeks	10.4	1 088	4 426	4.07	256
9F......	Kentucky bluegrass	5 weeks	12.6	1 088	5 808	5.34	236
10G.....	Kentucky bluegrass	5 weeks	14.4	1 088	7 165	6.59	219
11H.....	Kentucky bluegrass	5 weeks	21.7	1 088	7 632	7.02	309
12E.....	Red clover	¾ blossoms brown	12.3	735	4 406	5.99	205
13F.....	Red clover	¾ blossoms brown	19.7	735	5 788	7.87	250
14G.....	Red clover	¾ blossoms brown	19.5	735	7 123	9.69	201
15H.....	Red clover	¾ blossoms brown	25.0	735	7 633	10.39	241
16E.....	Red clover	¼ bloom	13.9	860	4 626	5.38	258
17F.....	Red clover	¼ bloom	16.7	860	6 010	6.99	239
18G.....	Red clover	¼ bloom	17.5	860	7 265	8.45	207
19H.....	Red clover	¼ bloom	22.0	860	7 735	8.99	245
20I.....	Reed canary grass	6 to 10 inches	7.4	825	4 745	5.75	129
21J.....	Reed canary grass	6 to 10 inches	14.8	825	5 346	6.48	228
22K.....	Reed canary grass	6 to 10 inches	15.6	825	6 960	8.44	185
23L.....	Reed canary grass	6 to 10 inches	15.0	825	6 677	8.09	185
24I.....	Bromegrass	4 to 8 inches[b]	8.5	699	5 125	7.33	116
25J.....	Bromegrass	4 to 8 inches[b]	14.3	699	5 889	8.42	170
26K.....	Bromegrass	4 to 8 inches[b]	14.9	699	7 204	10.31	145
27L.....	Bromegrass	4 to 8 inches[b]	12.5	699	7 022	10.05	124

[a]Stage of maturity at time of grazing. [b]Late fall growth that contained some older forage.

daily 1.82, 2.68, 1.87, and 1.85 pounds of dry forage per hundred pounds of live weight.

These analyses, altho based on a few cases, partially bear out the above observation on the relative rates of dry-matter consumption of animals of different weights. The available data do not show a reliable relationship between size of steer and rate of consumption when measured as a percentage of the steer's live weight. This emphasizes the advisability of using the relationship between the amount of forage actually consumed and the amount of that forage needed to maintain the net energy balance of the steer. For this reason most of the statistical analysis contained in this bulletin employs the net energy maintenance relationships.

An analysis, Table 19, of the intakes of steers E, F, G, and H while grazing on three forages was made on this basis and showed that they consumed 240, 242, 209, and 265 percent of their respective maintenance requirements. This shows that by expressing their consumption in terms of their actual needs instead of their live weight, the effect of size on rate of consumption is mostly eliminated, and appears to justify further the use of the net energy maintenance relationship in these studies.

How well variations due to size of steer are reduced is shown by a further analysis in which the experiments were grouped according to forages: bluegrass (Experiments 8E to 11H), red clover (Experiments 12E to 15H and Experiments 16E to 19H), and alfalfa (Experiments 3A to 7D). This arrangement of data, with the exception of that pertaining to alfalfa, places in a single group the rates of consumption of the four different-sized steers that were grazing on the same forage.

The coefficients of variation, which are the standard errors expressed as a percentage of the mean values, were calculated for the above forage groups when the level of feed intake was measured by both methods. When the level of feed intake was expressed as percentage of live weight, the coefficients of variation were 21.06, 18.40, 24.94 and 9.87 respectively. When the level of feed intake was expressed as percentage of the net energy maintenance requirement, the coefficients of variation were 15.31, 11.22, 9.29, and 4.49 percent respectively.

The foregoing analysis led the authors to the conclusion that, for the purposes of this study, the best method of comparing rates of consumption was the use of percentages of net energy maintenance requirements.

ACCURACY OF THE DATA

The degree of accuracy of the experimental results obtained in this investigation depends largely on two factors: (1) the degree of accuracy of the sampling and weighing; and (2) whether or not the ratio between dry-matter intake and dry-matter defecation during the digestion period holds true for the consumption period. The design and adjustment of the equipment, as already stated, successfully prevented any loss of feces, and at the same time permitted a high degree of freedom for the steers. The design and adjustment of the equipment consequently are not considered to be sources of error large enough to affect greatly the accuracy of the results.

Accuracy of the Sampling and Weighing

Great care was taken in sampling the forage, orts, and feces during all experiments. Airtight 1-pound coffee cans were used for transporting all samples from the barn to the laboratory. Careful records of all samples were kept at both the barn and the laboratory. In determining the dry-matter contents 100-gram samples of forage and orts, and 200-gram samples of feces were used.

All weighings of forage, orts, and feces were made on tested no-spring scales graduated to one-tenth of a pound and easily read to smaller amounts. In weighing the dry-matter samples, balances accurate to less than one-tenth of a gram were used. These samples were dried until they stopped losing weight in a thermostatically controlled electric oven maintained at a temperature of about 65° C.

The accuracy of the sampling of forage during the digestion period is indicated by the close agreement of the data from two duplications. The forage fed in Experiments 4C and 5D was identical, and was cut, fed, and sampled at the same time for both steers, duplicate samples being taken of both the morning and the night feeds. The samples for Experiment 4C averaged 26.0 percent dry matter, and the duplicate samples taken for Experiment 5D averaged 25.8 percent. A similar check was possible in Experiments 6C and 7D, in which the same forage was fed in both experiments but was sampled separately for each. The average dry-matter content of the samples for Experiment 6C was 29.4 percent, and for Experiment 7D, 29.7 percent.

These two checks indicate that the total error in sampling and analyzing the forage for dry-matter content was somewhat less than 1 percent. Such orts as were present were sampled and analyzed with the same care.

The fecal collections were sampled immediately after weighing, and care was exercised to obtain a representative sample. Because the total dry matter contained in the collection was the only item of interest, any evaporation from the feces collections could not influence the accuracy of the experiments except when this evaporation occurred between the time the feces collections were weighed and the time they were sampled. The sampling and analyzing of the feces were probably as accurate as the forage sampling discussed above.

No accurate determination was made of the average daily gains or losses of the steers during either period of the experiments, for the live weights of the steers, as already mentioned, do not enter into the operation of the method here used except as a means of describing the steers and of calculating their maintenance requirement. Accurate single-day weights consequently were obtained only at the beginning and at the end of each experiment. If average daily gains or losses were to be determined, daily weights and periods of experimentation longer than those in this investigation would be needed.

Reliability of the Ratio Between Dry-Matter Consumption and Defecation

If the weighing, sampling, and dry-matter analyses were accurate, the total net accuracy of each experiment, provided the dry matter defecated during the consumption period was accurately determined, depends largely on the reliability of the percentage relationship between the consumption and the defecation of dry matter, which was determined during the digestion period of each experiment.

The accuracy or reliability of this coefficient for use with the dry-matter defecation in estimating consumption was measured statistically by using the coefficient and the daily dry-matter defecations during the digestion period to estimate the dry-matter consumptions for the corresponding days. The estimated daily dry-matter consumptions were then compared with the known consumptions, and the standard error of the mean estimated forage consumption was computed.[12*]

In using this standard error of the digestion-period data as a measure of the corresponding error presumed to exist in the consumption-period data, it is necessary to know the relative variability of dry-matter consumption during the two periods of each experiment. If greater variation existed during the consumption period, it is logical to assume that some of this increased variation might occur just before either end of the collection period and might thereby increase the error of estimate over that found in the digestion period.

To determine whether the daily dry-matter intake fluctuated more during the consumption periods than it did during the digestion periods, the daily defecations of dry matter during both periods were analyzed statistically and their coefficients of variation were determined. These coefficients of variation of the twenty-seven digestion periods averaged 11.8, and the coefficients of variation of the twenty-seven consumption periods averaged 11.5, indicating that the dry-matter defecation and therefore probably the daily intake of dry matter during the grazing periods was as nearly constant as the daily intake of dry matter during the digestion periods.

On the basis of accepted statistical procedure it is safe to conclude that the calculated standard error of estimate tests the reliability of the coefficient in estimating not only the mean daily dry-matter consumption during the digestion period, but also the mean daily dry-matter consumption from the dry-matter defecation during the consumption period. In short, the calculated standard error of estimate indicates the error involved in using the consumption-defecation coefficient for predicting the dry-matter consumption from the dry-matter defecations during the eight-day consumption period.

Expressed as pounds of dry matter, the standard errors of the mean calculated consumptions for the twenty-seven experiments are listed in Table 13. These standard errors have been corrected by Ezekiel's formula[12*] for the small number of cases, or more correctly the degrees of freedom, in the samples from which they were computed. This correction increases the standard errors of estimate for the samples until they represent the true standard errors of estimate for the universes from which the small samples have been drawn.

These standard errors of estimate, if successfully corrected, indicate the range, above and below the respective calculated mean dry-matter consumption, within which the chances are approximately 2:1 that the true mean dry-matter consumption lies. That the true mean consumption lies within a range of twice these standard errors above and below their respective means, the odds would be approximately 20:1.

Miles's[26*] interpretation of "Student's"[45, 46*] work with small samples shows that Ezekiel's correction as used above is quite accurate. However, the odds that a distance equal to twice the corrected standard errors above and below their calculated mean consumptions would include the true mean consumptions are found to be more nearly 15:1 than 20:1.

The standard errors listed in the third column of Table 13 apply to the mean daily dry-matter intakes during the digestion periods. For the usually larger consumption-period mean intakes, the standard errors were corrected (sixth column, Table 13) so as to bear the same percentage relationships to the larger means of the consumption period

TABLE 13.—STANDARD ERRORS OF MEAN ESTIMATED FORAGE CONSUMPTION IN THE TWENTY-SEVEN EXPERIMENTS

Experiment and steer	Mean daily dry-matter intake, digestion period	Standard error of mean estimate,[a] odds 2:1	Standard error in percent of digestion-period mean[b]	Mean daily dry-matter intake, consumption period	Standard error corrected for increase in level of consumption
	lb.	*lb.*	*perct.*	*lb.*	*lb.*
1A	13.7	.46	3.35	25.8	.86
2B	10.8	.37	3.43	12.3	.42
3A	15.8	.87	5.51	13.1	.72
4C	8.6	.34	3.95	10.5	.41
5D	12.0	.39	3.25	12.0	.39
6C	10.0	.57	5.70	10.2	.58
7D	13.6	.71	5.22	12.0	.63
8E	7.5	.32	4.27	10.4	.44
9F	9.6	.54	5.62	12.6	.71
10G	13.6	.94	6.91	14.4	1.00
11H	15.9	.78	4.91	21.7	1.07
12E	6.6	.34	5.15	12.3	.63
13F	9.9	.35	3.54	19.7	.70
14G	13.2	.55	4.17	19.5	.81
15H	16.4	.76	4.63	25.0	1.16
16E	7.7	.25	3.25	13.9	.45
17F	10.2	.53	5.20	16.7	.87
18G	12.8	.59	4.61	17.5	.81
19H	15.1	.99	6.56	22.0	1.44
20I	3.4	.24	7.06	7.4	.52
21J	5.4	.39	7.22	14.8	1.07
22K	7.5	.63	8.40	15.6	1.31
23L	6.2	.46	7.42	15.0	1.11
24I	5.6	.15	2.68	8.5	.23
25J	....[c]	...	....	14.3	...
26K	9.7	.33	3.40	14.9	.51
27L	9.7	.42	4.34	12.5	.54

[a]Corrected for number of cases by Ezekiel's formula.[12*]
[b]The average standard error of the mean estimate, in percent of mean is 4.99 for the twenty-seven experiments.
[c]No digestion trial was run (see footnote, page 470).

as the corresponding uncorrected standard errors bear to the smaller means of the digestion period.

Example of Use of Standard Errors. Proper use of the standard errors listed in Table 13 may be exemplified in Experiment 13F. The mean daily dry-matter consumption of steer "J" was calculated with the aid of the consumption-defecation ratio to be 19.7 pounds (Table 7), the corrected standard error of which was .70 pound and the doubled corrected error consequently 1.40 pounds. This means that by odds of about 2:1 the mean daily quantity of dry matter actually consumed by the steer was between 19 and 20.4 pounds, or by odds of about 15:1 this consumption was somewhere between 18.3 and 21.1 pounds.

The average standard error of the mean calculated daily dry-matter consumption for the twenty-seven experiments when expressed as a percentage of the mean was 4.99 percent (Table 13), a figure that agrees closely with the results of the study by Schneider *et al*[38*] on the reliability of coefficients of digestibility. The probable error was equal to .6745 times the standard error, or 3.37 percent.

Much of the error involved was no doubt due to the fact that the digestion periods of the first twenty-three experiments did not conform to the best standards for nutritional experiments because there was some fluctuation in daily dry-matter intake. But inasmuch as Mitchell *et al* had shown[31*] that digestion coefficients based on three-day periods when dry-matter intake was held constant were almost as accurate as those based on fourteen-day periods, it was thought that the eight-day period used here would be long enough to reduce the errors involved to a reasonably small size.

To determine, if possible, the error caused by the fluctuations in daily dry-matter intake, a detailed statistical analysis of the data collected during the digestion periods of the first nineteen experiments was made.

Because the undigested part of the forage consumed on any one day probably was not defecated on that same day, the daily dry-matter defecations were lagged one, two, and three days. In other words, the dry-matter consumption of June 1 was compared with the dry-matter defecations of June 1, 2, 3, and 4; and the other days of the digestion period were treated likewise. If a definite relationship holds true for the rates of consumption and defecation, variations in the dry-matter intake should cause corresponding variations in the dry-matter defecations perhaps one, two, or three days later. The failure to regulate strictly the amount of dry matter consumed daily would correspondingly affect the reliability of the coefficient of "non-digestion," or the ratio between dry-matter defecation and intake.

The standard errors of the mean estimated dry-matter consumption were then determined, by the method previously mentioned, for the data treated with no lag, and with one-, two-, and three-day lags (Table 14). If the relative size of the dry-matter intake of every day of the digestion periods had a definite influence on the relative amounts of dry matter defecated on a particular succeeding day, the correct relationship should be revealed by this analysis.

Tho there proved to be very little difference, the data as originally collected with no lag had most frequently the smallest standard error of mean estimate and the lowest average error for the nineteen experiments. So far as variation in dry-matter intake during the digestion period is concerned, the reliability of the results was apparently not seriously impaired.

Error Reduced by Use of Electric Quick-Drier

The use of the defecation-consumption ratio obtained during the digestion period for measuring the dry-matter consumption during the consumption period, constituted in itself one source of error during the first twenty-three experiments, as suggested on page 482. The reason for this was the small but unavoidable fluctuation in daily dry-

TABLE 14.—STANDARD ERRORS OF THE MEAN ESTIMATED DRY-MATTER CONSUMPTION DURING THE DIGESTION PERIODS WHEN THE DRY-MATTER DEFECATIONS ARE GIVEN NO LAG, AND ONE-, TWO-, AND THREE-DAY LAGS[a]

Experiment and steer	Standard errors of mean estimated consumption			
	No lag	One-day lag	Two-day lag	Three-day lag
	lb.	*lb.*	*lb.*	*lb.*
1A	.46	.55	.67	.84
2B	.37	.51	.57	.42
3A	.87	1.23	1.20	1.34
4C	.34	.34	.60	.42
5D	.39	.40	.48	.44
6C	.57	.54	.73	.93
7D	.71	.63	.59	.48
8E	.32	.36	.51	.38
9F	.54	.52	.50	.47
10G	.94	.97	.34	.33
11H	.78	.79	.58	.45
12E	.34	.24	.45	.43
13F	.35	.37	.48	.46
14G	.55	.20	.80	.33
15H	.76	.96	.74	.85
16E	.25	.36	.42	.35
17F	.53	.70	.53	.56
18G	.59	.86	.90	.68
19H	.99	1.11	1.24	.88
Average	.56	.61	.65	.58
Number of times when error was smallest	10	3	1	5

[a]See page 485 for method used in calculating.

matter intakes during the digestion periods in these experiments. Inasmuch as the exact percentage of dry matter in the forage could not be determined before feeding, a constant amount of green forage was fed in the hope that the percentage and consequently the total amount of dry matter would not fluctuate greatly from day to day. But in later experiments, in order to regulate exactly the amount of dry-matter consumption during the digestion periods, the electric quick-drier described on page 455 was used. By the use of this device the percentage of dry matter in the green forage could be determined immediately after cutting, and then the proper amount of the forage could be fed to insure a fixed daily intake of dry matter for each steer. The quick-drier was used with marked success in Experiments 24I, 26K, and 27L.

The forage used in these three experiments was bromegrass. It varied so much in dry-matter content that an absolute check was not made; but enough data were collected to indicate that the drier removed practically all of the moisture from duplicate forage samples in one and one-half hours. Probably two hours of drying would remove *all* the moisture.

During the time that the forage samples were being dried, the sacks of fresh forage were kept closely covered to prevent evaporation. Once the percentage of dry matter in the forage was determined, it was a simple matter to calculate the amount of green forage needed to provide the predetermined level of dry-matter intake.

The use of this drier, resulting in almost constant dry-matter intake, reduced the standard error of estimate of the calculated forage consumption from an average of 5.19 percent for the first twenty-three experiments to 3.47 percent (Table 13, column 4) for the three experiments in which the drier was employed.

That 3.47 percent of error still remained was perhaps partly due to the fact that the quick-dried samples were not dried quite long enough and that the forage used varied so greatly in dry-matter content. An error of something less than one percent may be expected in sampling under ideal conditions. The chief reason for the remaining error was no doubt the use of the dry-matter percentages determined on oven-dried samples as the standard, rather than the percentages of the quick-dried samples. These dry-matter percentages determined on oven-dried samples indicated a larger apparent fluctuation in dry-matter intake than actually occurred.

Use of the dry-matter percentages as determined by the quick-drying equipment in calculating the standard error of estimate would reduce this calculated error considerably. Such a procedure appears to be justified in future work of this nature.

Errors Caused by Variations in Total Ash Content of Feces

In the course of the first two seasons of investigation, the question arose as to the possibility of the steers' ingesting during the consumption periods enough dirt to affect the accuracy of the method being used. In order to test this possibility, dry-matter samples of feces for both the digestion and the consumption periods in three 1934 experiments were saved and chemical analyses[a] for percentage of total ash were made. The steers, as in the other experiments, received the same kind of forage in the two periods.

No consistent difference between the amounts of ash in the two periods was revealed. In two experiments, 8E and 19H, the consumption-period feces contained more total ash than the digestion-period feces (2.69 and .54 percent respectively), whereas in the third, Experiment 14G, the digestion-period feces contained 4.67 percent more than was found in feces during the consumption period.

[a]The authors are indebted to the division of Animal Nutrition of the Department of Animal Husbandry for these analyses.

These changes in the percentage of total ash in the dry feces from one period to the other indicate a possible average error of 2.7 percent in the calculated forage consumption during these experiments, no matter where the added ash may have come from.

For this reason the percentages of total ash in the digestion- and in the consumption-period feces were determined for all of the 1935 experiments (Table 15). In two of the eight experiments, the digestion-period feces contained a higher percentage of total ash than

TABLE 15.—POSSIBLE ERRORS DUE TO CHANGES IN TOTAL ASH CONTENT OF DRY FECES

Experiment	Total ash in feces		Difference: consumption period *minus* digestion period	Daily dry-matter consumption		Error eliminated by ash correction
	Digestion period	Consumption period		Uncorrected	Corrected for ash variation	
	perct.	*perct.*	*perct.*	*lb.*	*lb.*	*perct.*
20	26.80	27.01	+ .21	7.4	7.4	0
21	27.36	25.75	−1.61	14.8	14.6	1.37
22	28.57	27.79	− .78	15.6	15.5	.65
23	25.80	28.67	+2.87	15.0	15.5	3.23
24	19.08	21.00	+1.92	8.5	8.6	1.16
25	.....	21.05	+3.19[a]	14.3	14.8	3.38
26	19.19	22.06	+2.87	14.9	15.3	2.61
27	18.74	23.51	+4.77	12.5	13.2	5.30
Average error eliminated	.....	.....	......	....	....	2.21

[a]No digestion trial was run on this steer. (See footnote, page 470.) This figure is an average of the other three experiments in this series.

did the consumption-period feces. The average possible error due to changes in the total ash content of the feces in these eight experiments was found to be 2.21 percent.

The data on forage consumptions for these eight experiments in 1935 have been corrected and this error of 2.21 percent removed. The similar error in the first nineteen experiments has not been removed because it is impossible to determine, except by chemical analysis of the feces, how large the error is and whether it is a negative or a positive error.

Where the percentage of total ash was greater for the consumption-period feces than it was for the digestion-period feces the increase might be explained on the theory that the steers ate a sufficient amount of dirt while grazing to bring about the rise in ash content of the feces. But where the reverse was true, and the digestion-period feces contained the higher percentage of total ash, such an explanation obviously could not be made, because the steers had no access to dirt during the digestion period. The most probable explanation, therefore, of these inconsistent variations lies in the fact that animals are known to excrete variable amounts of inorganic matter from their bodies. The fact that the consumption-period feces were not consistently higher in total ash than were the digestion-period feces indicates that the steers did not eat any appreciable amount of dirt while grazing.

Whatever may have been the source of the added inorganic matter, the fact remains that its presence in the feces causes an average error of about 2.5 percent in the calculated forage consumption unless correction is made for it in the calculations. This fact is obvious, for no matter whether the increase in the percentage of total ash content of the feces was caused by the animal consuming dirt or by the excretion of inorganic matter from its body at an accelerated rate, the increase represents dry matter excreted which probably has originated from sources other than the forage ingested during the trial periods.

In rare cases where excessive dust on the forage might cause an increase in the percentage of total ash in the feces during the consumption period, correction must also be made for this increase, because the excess inorganic matter ingested, as dust, is (relatively) indigestible and therefore tends to upset the relationship between dry matter consumed and dry matter defecated.

The added labor involved in running total ash analyses on both the digestion-period and consumption-period feces would be justified if an error of approximately 2.5 percent in the results is thereby eliminated.

Other Possibilities of Error

Other possibilities of error in these investigations have been suggested.

Difference in Level of Feeding.—The lower level of feeding during the digestion period, with the exception of two experiments, than during the consumption period might be thought to be a source of error. In the twenty-seven experiments, the steers consumed, on an average, 65 percent as much dry matter during the digestion periods as they did during the corresponding consumption periods. The effect which this change in level of feed intake may have had on the relative digestibility of the dry matter during the two periods is not believed to be significant.

A number of years ago there was considerable discussion of the effect of the level of feeding on the digestibility[a] of dry matter, and one study[32*] concluded with the statement that "the cause of the

[a]Apparent digestibility of dry matter was determined in all experiments conducted during this investigation.

differences in digestibility induced by differences in the amounts of feed consumed seems to be the proportion of hay in the ration." A careful analysis of the data presented in the above publication fails to indicate any significant differences in the digestibility of dry matter at the different levels of feeding due to an increased proportion of hay feed.

The exact opposite of the above view is held by most authorities in animal nutrition at the present time. In 1920, Honcamp and Koch[23*] fed a ration composed entirely of clover hay to sheep. The sheep were fed at three levels—600, 900 and 1,200 grams, and their coefficients of digestibility of the dry matter were 56.3, 56.2 and 55.5 percent respectively. In 1935 Watson, *et al.*,[52*] fed a ration of mixed clover-and-grass hay to four 985-pound Shorthorn steers. During separate digestion trials each steer was fed at levels of 4.5, 6.0, 7.5 and 9.0 kilograms per day, and the average digestibility of the dry matter at these four levels was 55.7, 56.2, 56.0, and 55.2 percent respectively. The difference in average digestibility of dry matter at the lowest and at the highest levels was only .5 percent, whereas the standard error of that difference was .68 percent. The coefficients of variation of the digestibility of the dry matter by *each* of the four steers when fed at the four levels were 0.73, 0.80, 2.00 and 0.69 respectively. And when the record of *all* four steers at each of the four levels of feeding was studied statistically it was found that the coefficients of variation were 2.08, 1.81, 1.58, and 1.30 from the lower to the higher levels respectively. The very small differences observed, together with the unusual consistency of the results obtained, strongly justify the conclusion of Watson *et al*, that—"For the range of 4.5 to 9.0 kilogrammes per day, the plane of nutrition did not significantly affect the coefficients of digestibility."

On the basis of these two reports, together with several similar ones which have not been referred to, it appears safe to conclude that the relatively small change in level of dry-matter intake (35 percent) in the experiments reported in this bulletin did not affect the digestibility of the dry matter to any appreciable extent.

Differences in Maturity of Forage.—The fact that the forage was in a slightly more advanced stage of maturity during the consumption period than during the digestion period might also be considered to be a source of error in the ratio between defecation and consumption of dry matter.

In order to introduce as small an error as possible here, the grazing method was arranged so that only five or six days elapsed from the time the digestion period ended until the consumption period began, and the midpoints of the two periods were thus only thirteen or fourteen days apart. A more nearly ideal arrangement would be to split the field in half and clip the two halves at different dates so that the ages of the forages fed during the digestion period and grazed during the consumption period would be identical. This was done in Experiments 16E to 19H, but was not possible in the others.

That such differences in maturity of the pasture grasses and legumes as would result from the lapse of about two weeks between the midpoints of the two periods actually introduced no errors of any consequence is indicated by the data from both this and other investigations. Thus the dry matter of alfalfa in the ¼-, ½-, and ¾-bloom stages was found by Sotola[41*] to be digested to the extent of 54, 55, and 51 percent respectively when fed to sheep. And in the present study, the data of Experiments 12E to 15H and 16E to 19H gave a good comparison of the effect of advanced maturity on the digestibility of red clover. The dry matter of the younger clover was less digestible in three of the four cases, and was 1.6 percent less digestible on the average. This difference was not statistically significant, however, for the odds in favor of a difference in digestibility between the dry matter of the two forages were 2.2:1 by the binomial method, and 12:1 by Student's method.

In an investigation of pasture grass in normal seasons Woodman *et al*[58*] found it to be fully as digestible when four weeks old as when younger. They also found no depression in digestibility of the crude fibre of five-week-old grass, indicating no lignification up to that age. They did find some depression in the digestibility of the total organic matter of the five-week-old grass, but this depression was variable and of no great magnitude.

Total Error in Data Not Large

The evidence reported in the foregoing sections bears out the assumption that no large error was introduced into the results by the experimental procedure used during the experiments.

As to the reliability of all twenty-seven experiments, it appears that:

1. The error in sampling and analysis probably averaged less than 1 percent.

2. The probable error incurred by using the ratio between dry-matter consumption and defecation during the digestion period as a means of estimating the dry-matter consumption from the dry-matter defecation during the consumption period, was found to be, on the average, approximately 3⅓ percent.

3. Such error as may have been caused by variation in the rate of defecation of inorganic matter from the steers' bodies, indicated by variations in the total ash content of the dry feces, was not, on an average, greater than 2½ percent in the first nineteen experiments. This error was eliminated in the last eight experiments.

4. Other than the foregoing three errors, there was evidently none of sufficient magnitude to be of any serious consequence.

5. The total error in the twenty-seven experiments was on an average probably not greater than 6 percent. This total error was slightly reduced during the later experiments.

6. The total error was small in comparison with the errors found in similar investigations in which other methods have been used.

DISCUSSION OF THE FORAGE-CONSUMPTION DATA

It is the purpose of this section to define statistically the probable limits of consumption that may be expected from steers on the various forages which have been tested, and to discuss the effect of three factors—species of forage, stage of maturity of forage, and size of steer—on the forage consumption of steers as determined or indicated by a statistical analysis of the data. A short résumé of closely related previous work has been included.

Actual and Relative Rates of Consumption, and Probable Limits to the Average Consumption of Similar Groups of Steers on Similar Forages

Averages of the results obtained with the different forages are presented in Table 16. By using the average rate of consumption of Kentucky bluegrass as a base, or 100, the relative rates of consumption of the other forages have been computed. These are presented merely to clarify the discussion. The use to which these relatives may be put is somewhat limited, and the original values on which they have been based should be used in preference to them in most cases where accuracy rather than convenience is desired.

In the last column of Table 16 are listed the probable limits within which the average rates of consumption of similar groups of steers grazing on similar forages may be expected to lie. These limits have been determined statistically with odds set at 20:1.

For example, the odds are 20:1 that the average daily rate of forage consumption of any group of five normal, moderately-fleshed beef

TABLE 16.—AVERAGE ACTUAL AND RELATIVE RATES OF FORAGE CONSUMPTION OBSERVED, AND THE LIMITS WITHIN WHICH THE AVERAGE RATES OF CONSUMPTION OF SIMILAR GROUPS OF STEERS MAY BE EXPECTED TO LIE

Forage tested	Number of experiments	Average percent of net energy maintenance requirement consumed[a]	Relative rates of consumption	Probable limits of consumption (percent of maintenance requirement)[b]
			perct.	
Five-week Kentucky bluegrass....	5	270	100	227 to 313
Quarter-bloom red clover.........	4	237	88	215 to 259
Mature red clover[c]...............	4	224	83	199 to 249
Reed canary grass 8 to 10 inches high	4	182	67	142 to 222
Late bromegrass[d]................	4	139	51	116 to 162
Full-bloom alfalfa................	5	129	48	124 to 134

[a]The amount of forage fed at the maintenance level required to furnish a maintenance ration of net energy has been taken as the unit for measuring the rates of consumption. No allowance has been made for the reduced utilization of that portion of the gross energy consumed above the maintenance level.

[b]Determined statistically using 20:1 odds. These limits apply to the average consumption of groups of steers similar to those used in these experiments.

[c]Three-quarters of the blossoms had turned brown.

[d]Contained some older forage but was mainly four to eight inches high. Had nearly ceased its active growth for the season.

steers grazing on five-week-old Kentucky bluegrass will lie between 227 and 313 percent of the amount of forage needed to furnish their daily maintenance requirements of net energy, if other conditions are reasonably similar to those of this investigation.

These limits, being based on so few observations, are necessarily too wide to be of the greatest practical importance. However, the limits do serve to indicate the range within which future observations may be expected to lie.

Consumption of Different Species of Forage by Grazing Steers

Stapledon[42*] has stated, "Probably of greater importance than the inherent nutritive value of herbage is its palatability." Inasmuch as this statement voices the opinion of many authorities on pasture utilization, it illustrates the value of accurate consumption studies.

The twenty-seven experiments provide fourteen satisfactory comparisons concerning the rates of consumption of different species of forage plants by grazing steers. The essential data concerning these comparisons are given in Table 17.

It must be distinctly understood that the probable limits of and differences in rates of forage consumption presented in this section are intended to apply only to forages comparable in species, strain, stage of maturity, and chemical composition to those used in this study and when grazed by steers similar to those described in this bulletin and under climatic and soil conditions similar to those prevailing during the various trials. Just how strictly comparable to those herein described these soil, plant, animal, and climatic factors must be in order to apply these results safely, remains to be decided by further work in this field.

TABLE 17.—MINIMUM NET DIFFERENCES IN CONSUMPTION DUE TO DIFFERENCES IN THE FORAGES TESTED

First forage	Average rate of consumption[a]	Second forage	Average rate of consumption[a]	Difference between average rates of consumption	Standard error of difference	Odds that true mean difference exceeds zero[b]	Minimum net difference due to forage (20:1 odds)[c]
	perct.		*perct.*				
Five-week Kentucky bluegrass	270	Old alfalfa	129	141	21.6	12 000:1	100
Young red clover	237	Old alfalfa	129	108	11.3	400 000:1	86
Five-week Kentucky bluegrass	270	Late bromegrass	139	131	24.4	1 899:1	84
Old red clover	224	Old alfalfa	129	95	12.8	25 000:1	70
Young red clover	237	Late bromegrass	139	98	16.0	2 164:1	66
Old red clover	224	Late bromegrass	139	85	17.1	796:1	51
Five-week Kentucky bluegrass	270	Yound reed canary grass	182	88	29.3	99:1	32
Young reed canary grass	182	Late bromegrass	139	43	11.0[d]	66:1	16
Young reed canary grass	182	Old alfalfa	129	53	20.1	59:1	14
Young red clover	237	Young reed canary grass	182	55	22.8	37:1	10
Young red clover	237	Old red clover	224	13	13.9[d]	4:1	0
Five-week Kentucky bluegrass	270	Young red clover	237	33	24.1	8:1	0
Five-week Kentucky bluegrass	270	Old red clover	224	46	24.9	18:1	0
Old red clover	224	Young reed canary grass	182	42	23.6	15:1	0
Late bromegrass	139	Old alfalfa	129	10	11.9	4:1	0

[a]Percentage of maintenance requirements. The amount of each forage required to furnish a maintenance ration of net energy, when fed at the maintenance level, has been taken as the unit by which the rates of consumption are measured. No allowance has been made for the reduced utilization of that portion of the gross energy consumed above the maintenance level.

[b]From Miles.[26*]

[c]This minimum net difference was found by subtracting the maximum difference due to chance, with odds set at 20:1, from the actual difference. The necessary "t" values for odds of 20:1 were taken from Miles's table.[26*]

[d]These standard errors of the mean difference were computed by means of Student's formula because the same steers were used on both forages. All other standard errors were computed by Bessel's formula.

The differences observed between the rates of consumption by the steers while grazing on the various forages are of uncertain value for making comparisons unless a statistical determination of their reliability or significance is made. Such an analysis has been made and the results are given in the last four columns of Table 17: the differences between the average rates of consumption of the forages as compared; the standard errors of these differences, calculated, except as indicated, by Bessel's formula; the odds that true mean differences did exist; and finally the minimum net differences in consumption which are due to differences in the forages compared, after random variation has been removed with odds set at 20:1. This last measure is perhaps the most useful of all, because it forms a conservative measure of the superiority that the more palatable forage in each pair was found to have over the other forage with which it was compared.

According to the theory of statistics, these minimum net differences in rate of consumption should hold true for the average results obtained with any similar groups of steers grazing comparable forages and under conditions like those of this investigation. The minimum net differences recorded vary all the way from none to 100 percent of a maintenance requirement.

It should be noted that five-week-old Kentucky bluegrass, mature red clover, and quarter-bloom red clover all proved to be capable of inducing very significantly higher average rates of consumption than either full-bloom alfalfa or late fall bromegrass. Young reed canary grass was found to be superior to both the late bromegrass and the full-bloom alfalfa, but inferior to the Kentucky bluegrass and quarter-bloom red clover. No significant differences were found between the average rates of consumption by the steers while they were grazing on Kentucky bluegrass and on either the young or the older red clover, while grazing on older red clover and on young reed canary grass, or while grazing on late bromegrass and on full-bloom alfalfa.

Student's method[45, 46*] was used to test the reliability of the observed differences in the consumption of the young reed canary grass and the late bromegrass, and also of the young red clover and the older red clover. The method developed by "Student" may rightly be employed in testing the reliability of differences found in these comparisons, for the same steers were used to test both forages in each comparison, and other conditions also were comparable. By this method the rates of consumption of each of the four steers while grazing on the two forages being compared are paired and the differences between the members of the paired observations are used rather than between the means of the two groups of observations, as is done when Bessel's formula is used. Much of the variation caused by differences between steers is thus eliminated, and therefore the true reliability of the differences in rate of consumption caused by differences in the forages is measured. When this method is used a small number of paired comparisons usually give results equal in significance to those obtained by a greater number of nonpaired observations.

The results obtained in Experiment 1 on Kentucky bluegrass with steer "A" may thus be disregarded, and the results obtained on Kentucky bluegrass in Experiments 8E thru 11H may be compared with those obtained with the same steers on both the young and the older red clover. Student's method may then be used in measuring the significance of the differences observed.

The odds by this second method are 4.82:1 that five-week-old Kentucky bluegrass will be consumed at a higher rate than will quarter-bloom red clover, and 9.56:1 that five-week-old Kentucky bluegrass will be consumed at a higher rate than will mature red clover. Odds, respectively of 8:1 and 18:1 were obtained when all five Kentucky-bluegrass experiments were included and Bessel's formula was used in making the comparisons.

Both analyses thus fail to find any significant differences between the average rates of consumption of the steers while grazing on five-week-old Kentucky bluegrass, quarter-bloom red clover, and mature red clover. Further investigation may uncover small true differences and, if so, will probably rank the three forages in the order named.

Influence of Stage of Maturity of Red Clover on Its Consumption by Four Steers

Steers E, F, G, and H were used in Experiments 12E to 19H inclusive. The first four of these experiments dealt with red clover which had so advanced in maturity that three-fourths of the blossoms had turned brown. The second group of four experiments dealt with the second crop on the same field of red clover, in the quarter-bloom stage of maturity. By comparing the results obtained from these two groups of experiments, the effect of advanced maturity of red clover on the forage consumption of grazing steers may be tested without the disturbing element which would have been introduced by the use of different steers for the two sets of experiments. While the same field of clover was used in these two series of experiments, it is recognized that the arrangement was not ideal for eliminating all forage factors except maturity, because one test was made on the first crop and the other on second growth.

The differences found in the analysis and the reliability of these differences are shown in Table 18. While grazing the younger red clover, Experiments 16 to 19 inclusive, the four steers consumed on an average 237 percent of their maintenance requirements. These same four steers while grazing on the older red clover, Experiments 12 to 15 inclusive, consumed on an average 224 percent of their maintenance requirements.

The average difference of 13.0 points between the percentages of the maintenance requirements of the steers, in favor of the younger

TABLE 18.—THE EFFECT OF ADVANCING MATURITY IN RED CLOVER ON ITS CONSUMPTION BY GRAZING STEERS[a]

Steer	Rates of consumption[b]		Mean difference	Standard error of mean difference	Odds that there is a true mean difference[c]
	Quarter-bloom clover	Past-bloom clover			
	perct.	*perct.*			
E	258	205	....	....	....
F	239	250	....	....	....
G	207	201	....	....	....
H	245	241	....	....	....
Average	237	224	13	13.86	3.81 : 1

[a]Student's method[45*] used, for same steers were grazed on both forages.
[b]Percentages of maintenance requirements consumed by the steers, the maintenance requirement in each case being the amount of forage needed to maintain the energy balance of the steer used.
[c]Based on Miles's table of odds.[26*]

red clover, was found to be not significant, the odds being only 3.81:1. A difference of 33.40 points between the percentages of the maintenance requirements, or nearly three times the difference found, would be the lowest significant difference with odds of 20:1.

This statistical analysis indicates that, under the conditions prevailing during these tests and within the limits measured, the stage of maturity of red clover has no significant effect on the rate of its consumption by grazing steers, when rate of consumption is expressed as a percentage of that amount of forage required daily to maintain the net energy balance of the steer.

It is also of interest to note that in these experiments (see Table 7 for individual data) the advance in maturity of the red clover did not significantly affect the digestibility of its dry matter. This analysis, based on four comparisons, was made with the aid of Student's[45, 46*] method.

Forage Consumption of the Steers Classified by Weight

Steers E, F, G, and H were each used in three experiments, and were grazed on the same three forages during the season of 1934. By combining the results of the three experiments for each steer and averaging them, it was possible to determine what effect size of steer may have had on forage consumption. Similar averages and comparisons were made for steers I, J, K, and L, all of which were grazed on two forages.

Altho there appeared to be no definite relationship between size of steer and forage consumption (Table 19), there were so few steers used to represent the different weights that the results have practically no statistical significance or reliability. These data are presented, however, so that they may be compared with results of future experiments.

Thus there was no evidence of a consistent tendency of forage consumption, when expressed in terms of percentage of maintenance

TABLE 19.—FORAGE CONSUMPTION OF STEERS CLASSIFIED AS TO WEIGHT OF STEER

Steer	Experiments	Average weight of steer	Percent of maintenance requirement consumed[a]	Pounds of dry matter consumed daily per 100 pounds live weight
First comparison—Kentucky bluegrass and red clover				
		lb.		*lb.*
E	8, 12, 16	373	240	3.26
F	9, 13, 17	596	242	2.74
G	10, 14, 18	847	209	2.03
H	11, 15, 19	948	265	2.41
Second comparison—reed canary grass and bromegrass				
I	20, 24	440	122	1.82
J	21, 25	552	199	2.68
K	22, 26	825	165	1.87
L	23, 27	780	154	1.85

[a]Maintenance requirement of each steer is the amount of dry forage needed to meet his daily requirements for net energy.

requirement, to vary with the weight of the steer. But when the forage consumption is expressed in terms of pounds of dry forage per day per 100 pounds of steer, a very slight tendency for the smaller steers to consume amounts equal to a larger percentage of their live weight is evident. The last column of Table 19 shows that, in the first comparison, the smallest steer had the highest forage consumption per unit of weight, and the second largest steer had the smallest. In the second comparison, the second smallest steer had the largest consumption per unit of weight and the others were all approximately the same.

The results obtained with steers E and F are of interest in that both steers consumed approximately the same proportion of their actual needs for maintenance, but when their consumption was measured in terms of pounds per unit of live weight, a marked difference in rates of consumption was recorded.

The results reported for steers I and J offer further evidence which apparently justifies the current practice of relating forage intake to needs rather than to the more abstract measure, unit of body weight.

COMPARISON WITH SIMILAR PREVIOUS INVESTIGATIONS

Because pasture research is relatively young and previous methods of determining the forage consumption of grazing animals have been far from satisfactory from the standpoints both of accuracy and of practicability, very few data have been found with which to compare the results of the present investigation. Practically all of the references deal with the relative palatability of pasture forage species other than those dealt with in this present investigation. Other studies reported have been based almost entirely on observations and forage counts rather than on actual measurements of the forage consumption by the animals employed. For this reason the conclusions reached are listed as a matter of interest, but no detailed discussions are given. Neither is an attempt made to include a complete list of all the palatability and consumption studies which have been reported.

Palatability.—Fagan and Jones[13*] listed the relative amounts of seven pasture grasses eaten by grazing sheep. These were as follows:

Timothy	49	Cocksfoot	32
Italian ryegrass	45	Golden oatgrass	25
Meadow foxtail	33	Red fescue	17
Perennial ryegrass	32		

Milton[27*] listed the relative amounts of seven pasture forages eaten by grazing sheep as follows:

Lolium perenne	97	*Holcus lanatus*	75
Trifolium repens	80	*Poa trivialis*	68
Phleum pratensis	80	*Trifolium pratense*	66
Dactylis glomerata	78		

Milton[28*] also listed several forages in the order of their relative palatability for sheep, namely—red clover, white clover, timothy, orchard grass, perennial ryegrass, and rough-stalked meadow grass.

Numerous other similar reports dealing with relative palatability have been published. Only three references, however, that deal with comparisons of forages similar to those tested in the present investigation have been found. In one of these, by Davies,[9*] the following statements were made: "One reason why the clovers maintain a much more uniform palatability than the grasses is probably that under more or less constant grazing they never produce very much stemmy growth;" and, "Speaking generally, the stage of growth of the individual plants appears to be the dominating factor affecting palatability." In another, by Beaumont,[1*] the results of two experiments where dairy cows were allowed to choose between several pasture forages were reported. The order of preference in the first experiment was white clover, timothy, redtop, and Kentucky bluegrass. The order of preference in the second experiment was timothy, redtop, Italian ryegrass, English ryegrass, yellow oatgrass, meadow fescue, and reed canary grass, which was not eaten at all.

The interesting point in the above reports is that Davies ranked all clovers over the grasses and Beaumont ranked white clover over Kentucky bluegrass. Some agronomists have ranked the legumes according to palatability as follows: alfalfa, alsike clover, red clover, white clover, landino clover, mammoth red clover, lespedeza, and sweet clover.

None of these reports on palatability is in entire agreement with the results of the present study, nor are they in agreement with each other. Hopper and Nesbitt[24*] stated that "Brome grass is equal to timothy in feeding value [and] is one of the most palatable of pasture grasses." The digestion and consumption studies of the present investigation indicate that the above is not the case during the late fall season.

And in regard to reed canary grass, Wilkins and Hughes[53*] have recorded the observation that dairy cows, given free access to several species of pasture grasses, have indicated a liking for reed canary grass equal to that exhibited for Kentucky bluegrass, redtop, tall oatgrass, slender wheatgrass, crested wheatgrass, or rough-stalk meadow grass. The cows showed a much greater preference for reed canary grass than they did for orchard grass or any of the fescues. Canada bluegrass, smooth bromegrass and timothy were found to be more palatable than the reed canary grass. Legumes which were apparently more palatable than any of the pasture grasses were medium red clover and alsike clover. Alfalfa, white Dutch clover, and wild white clover were found to be consumed as readily as any of the most palatable grasses. These results obtained by Wilkins and Hughes obviously do not agree with those obtained by Beaumont, referred to above.

Inasmuch as it has been shown that previous methods of determining the forage intake of animals have been either inaccurate or carried out under artificial conditions or both, it seems unnecessary to summarize the few results which have been reported on actual amounts of forage consumed. If "relative palatability" and "relative rate of consumption" may be considered as synonymous terms, the data from these other investigations hardly agree with the results of the present investigation.[a]

[a]Unpublished results of experiments conducted by the Illinois Experiment Station show that rats given free access to different varieties of hybrid corns show a distinct preference for certain strains, but that when they are restricted to the apparently less palatable strains consumption is not reduced.

Effect of Size of Steer.—No studies of the effect of the size of a steer on his rate of forage consumption have been reported. It appears to be generally accepted, however, that smaller steers consume larger feeds of grain per unit of weight than do larger steers.[4*] Fattening pigs on full feed have also been found[37*] to consume a greater percentage of their live weight in grain when at the lighter weights than they do at the heavier weights. A very slight tendency toward this relationship was discovered for different sizes of steers grazing on pasture forages in the present investigation, as shown in Table 19.

The almost total lack of experimental results with which to compare the results of the investigation reported herein further emphasizes the need for this type of information.

SUMMARY

The effects of species of forage, stage of maturity of forage, and size of animal on the forage consumption of grazing steers have been found to be important aspects of the increasingly important pasture problem. The present investigations were undertaken (1) to determine the forage consumption of steers of several sizes grazing on forages of different species and stages of maturity, and (2) to discover any variations in forage consumption during the experiments that might result from differences in species of forage, stage of maturity of forage, or size of steer.

Method. As a practical means of obtaining the desired information, a specially devised harness and feces sack were used to collect the feces of a freely grazing steer, with a minimum of restraint on or discomfort to the steer. A new method of measuring consumption, employing this equipment and utilizing the reasonably constant relationship between dry matter consumed and dry matter defecated, was used in twenty-seven separate experiments dealing with twelve steers and seven pasture forages differing in species or stage of maturity.

The net energy maintenance requirements of each steer, the net energy values of the tested forages when fed at the maintenance level, and subsequently the pounds of the dry forage needed to provide a daily maintenance ration of net energy for each steer used were either determined or calculated. The rate of forage intake in each of the twenty-seven experiments was expressed by the ratio existing between the pounds of dry matter consumed daily and the pounds of that dry matter required to provide a daily maintenance ration of net energy.

Since this study deals primarily with *rate* of forage consumption

TABLE 20.—SUMMARY OF RESULTS, ALL TWENTY-SEVEN EXPERIMENTS

Experiment and steer	Forage tested	Stage of maturity of forage[a]	Dry-matter content of forage	Ratio of dry matter defecated to dry matter consumed	Calculated average daily dry-matter consumption	Standard error of estimate in percent of average consumption[b]	Average weight of steer	Daily maintenance requirement of steer[c]	Net energy per pound of dry forage[d]	Calculated amount of dry forage required daily for maintenance	Percent of maintenance requirement consumed[e]
			perct.	*perct.*	*lb.*	*lb.*	*lb.*	*Calories*	*Calories*	*lb.*	*perct.*
1A	Bluegrass	½ headed	40.7	36.4	25.8	.86	938	7 632	980	7.79	331
2B	Clover, mixed	¼ bloom	30.0	36.4	12.3	.42	535	5 508	860	6.40	192
3A	Alfalfa	¾ bloom	27.3	46.4	13.1	.72	988	7 857	760	10.34	127
4C	Alfalfa	¾ bloom	26.0	33.0	10.5	.41	602	5 909	760	7.78	135
5D	Alfalfa	¾ bloom	25.8	33.5	12.0	.39	758	6 738	760	8.87	135
6C	Alfalfa	Full bloom	29.4	37.1	10.2	.58	618	5 990	714	8.39	122
7D	Alfalfa	Full bloom	29.7	34.9	12.0	.63	775	6 820	714	9.55	126
8E	Bluegrass	5 weeks	31.2	30.7	10.4	.44	364	4 426	1 088	4.07	256
9F	Bluegrass	5 weeks	31.2	31.4	12.6	.71	584	5 808	1 088	5.34	236
10G	Bluegrass	5 weeks	31.2	29.1	14.4	1.00	844	7 165	1 088	6.59	219
11H	Bluegrass	5 weeks	31.2	26.7	21.7	1.07	940	7 632	1 088	7.02	309
12E	Red clover	¾ blossoms brown	32.9	36.8	12.3	.63	362	4 406	735	5.99	205
13F	Red clover	¾ blossoms brown	32.9	35.3	19.7	.70	582	5 788	735	7.87	250
14G	Red clover	¾ blossoms brown	32.9	35.2	19.5	.81	834	7 123	735	9.69	201
15H	Red clover	¾ blossoms brown	32.9	30.7	25.0	1.16	942	7 633	735	10.39	241
16E	Red clover	¼ bloom	25.6	36.7	13.9	.45	394	4 626	860	5.38	258
17F	Red clover	¼ bloom	25.6	36.8	16.7	.87	622	6 010	860	6.99	239
18G	Red clover	¼ bloom	25.6	36.4	17.5	.81	862	7 265	860	8.45	207
19H	Red clover	¼ bloom	25.6	34.6	22.0	1.44	963	7 735	860	8.99	245
20I	Reed canary grass	6 to 10 inches	21.6	40.7	7.4	.52	410	4 745	825	5.75	129
21J	Reed canary grass	6 to 10 inches	21.6	37.1	14.8	1.07	505	5 346	825	6.48	228
22K	Reed canary grass	6 to 10 inches	21.6	36.9	15.6	1.31	800	6 960	825	8.44	185
23L	Reed canary grass	6 to 10 inches	21.6	39.7	15.0	1.11	745	6 677	825	8.09	185
24I	Bromegrass	4 to 8 inches[f]	28.3	49.2	8.5	.23	470	5 125	699	7.33	116
25J	Bromegrass	4 to 8 inches[f]	28.3	48.2[g]	14.3	...	600	5 889	699	8.42	170
26K	Bromegrass	4 to 8 inches[f]	28.3	45.8	14.9	.51	850	7 204	699	10.31	145
27L	Bromegrass	4 to 8 inches[f]	28.3	49.6	12.5	.54	815	7 022	699	10.05	124

[a]Stage of maturity at time of grazing.

[b]Ezekiel,[12*] pp. 114, 121, 253.

[c]Mitchell, *et al*,[31*] p. 189—fasting heat production, 1,897 Calories per square meter of body surface (by Brody formula); Hall and Brody,[22*]—energy cost of locomotion, 33 Calories per 100 pounds live weight.

[d]These net-energy values have been calculated for the forages when fed at the maintenance level, and have been used merely as a basis for an index of consumption. No correction has been made for the reduced utilization of that portion of the gross energy consumed above the maintenance requirement.

[e]These values are intended to serve merely as an index of rate of consumption and should not be interpreted as representing relative nutritive values.

[f]The bromegrass, which contained some old growth, was tested in October after it had nearly ceased its active growth.

[g]Due to an unavoidable circumstance no digestion trial was run on this steer. An average of the coefficients obtained with the other three steers was used in this case.

rather than with *nutritive value* of the forage consumed, no attempt has been made to allow for the reduced utilization of that portion of the gross energy consumed above the maintenance level. These allowances, if desired, may be made at such time as they become definitely established. The relative ranking of the various forages would not be changed by such a manipulation, altho the observed differences would be somewhat lessened and the actual *rates* of consumption and their relation to carrying capacity or agronomic production studies would be partially confused.

Accuracy. Statistical analysis of the data from these experiments has shown the average probable error of the mean calculated forage consumption to be only 3.37 percent. Other sources of error make the total measurable error of the average experiment approximately 6 percent of the mean forage consumption. New equipment, particularly an electric quick-drier, and new technics reduced the total error to 3⅓ percent in the latest experiments.

Results. To permit easy comparison of the rates of consumption of the various forages, the rate of consumption of the Kentucky bluegrass may be taken as 100. The relative rates of consumption of the other forages tested were then: young red clover, 88; old red clover, 83; young reed canary grass, 67; late bromegrass, 51; and full-bloom alfalfa, 48. These relatives are, of course, based on the average percentages of the maintenance requirement consumed by the steers grazing on the various forages.

The actual consumption by the various steers grazing on the different forages, expressed in terms of percentage of maintenance requirements, was as follows: *Kentucky bluegrass,* 270 percent, average of five experiments, including four experiments with five-week-old bluegrass and one with grass that was approximately one-half headed; quarter-bloom *red clover,* 237 percent, average of four experiments; old *red clover,* three-fourths of blossoms brown, 224 percent, average of four experiments; young *reed canary grass,* 182 percent, average of four experiments; late *bromegrass,* 139 percent, average of four experiments; and full-bloom *alfalfa,* 129 percent, average of five experiments.

A single experiment was conducted on a mixture of red clover and alsike clover with some grasses and weeds. The primary object of this experiment was to check the accuracy of the old clipping method for determining the forage consumption of steers. An error of approximately 57 percent in the old clipping method was revealed. The steer consumed 192 percent of his maintenance requirement.

The minimum net differences between the average rates of consumption of groups of similar steers grazing on these various forages were calculated by substracting the expected random variation, with odds set at 20:1, from the actual differences observed. Five-week-old Kentucky bluegrass, quarter-bloom red clover and mature red clover were all found to be significantly superior to late bromegrass or full-bloom alfalfa, when judged on the basis of level of consumption induced. This superiority was found to vary from 51 to 100 percent of a maintenance ration in the different comparisons. Young reed canary grass was found to be slightly superior to late bromegrass or full-bloom alfalfa, while both quarter-bloom red clover and five-week-old Kentucky bluegrass were found to be somewhat better than young reed canary grass. Comparisons showing no significant differences were quarter-bloom red clover and mature red clover, five-week-old Kentucky bluegrass and either quarter-bloom or mature red clover, mature red clover and young reed canary grass, late bromegrass and full-bloom alfalfa.

A change in the maturity of medium red clover from the quarter-bloom stage to the stage where three-fourths of the blossoms had turned brown did not significantly affect its apparent digestibility or rate of consumption by the steers.

No definite relationship was discovered between size of steer and relative rate of forage consumption when rate of consumption was measured either in percent of maintenance requirement or in pounds of dry forage per unit of live weight. Because of the limited number of steers in each weight division, however, the data were not considered to be conclusive.

Atmospheric temperature and precipitation data for the three seasons were recorded, but no effect of these factors on the rate of forage consumption by the steers was discovered.

CONCLUSIONS

The data obtained in the twenty-seven grazing experiments support the following conclusions:

1. The method used in these experiments for determining the forage consumption of steers is more reliable than methods formerly used for this purpose.

2. Under conditions similar to those of this investigation, any five or more 400- to 1,000-pound, moderately fleshed, normal beef steers may be expected to consume, during grazing, on the average, the

following amounts of any one of the following forages, expressed as percentages of the net energy maintenance requirements of the steers:

Kentucky bluegrass, five weeks old, 227 to 313 percent
Red clover, quarter-bloom, 215 to 259 percent
Red clover on which three-fourths of the blossoms have turned brown, 199 to 249 percent
Reed canary grass, young second growth, eight to ten inches high, 142 to 222 percent
Bromegrass, late fall growth, 116 to 162 percent
Alfalfa, three-quarter and full bloom, 124 to 134 percent

3. The average consumption by any five or more 400- to 1,000-pound, moderately fleshed, normal beef steers while grazing on either five-week-old Kentucky bluegrass, quarter-bloom red clover, or mature red clover may be expected to be higher, by 51 to 100 percent of the amounts of forage needed to furnish their daily maintenance requirements of net energy, than it would be while the steers were grazing on either late fall bromegrass or full-bloom alfalfa.

4. When measured in the above manner five-week-old Kentucky bluegrass may be expected to be somewhat superior to young second-growth reed canary grass; young second-growth reed canary grass to be slightly superior to late fall bromegrass or full-bloom alfalfa; and quarter-bloom red clover to be a little better than young reed canary grass.

No significant differences are indicated between five-week-old Kentucky bluegrass and either quarter-bloom or mature red clover, between mature red clover and young reed canary grass, or between late fall bromegrass and full-bloom alfalfa.

5. An advance in the maturity of red clover from the quarter-bloom stage to the point at which three-fourths of the blossoms have turned brown, under conditions similar to those of this investigation, will not greatly affect either the apparent digestibility of the dry matter or the rate of forage consumption, as measured by percentage of net energy maintenance requirement consumed.

6. Species of forage grazed exerts a greater influence than size of steer on the rate of forage consumption, expressed as a percentage of net energy maintenance requirements, of 400- to 1,000-pound, moderately fleshed, normal beef steers.

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